JOURNAL

of the

RUBBER RESEARCH INSTITUTE

of

MALAYA

VOLUME 15 FIFTH PART 1958

Contents

J. Rubb. Res. Inst.
Malaya 15 (1958)

DEFOLIATION OF HEVEA BRASILIENSIS BY AERIAL SPRAYING 241
F. W. Hutchison

PINK DISEASE OF HEVEA CAUSED BY CORTICIUM SALMONICOLOR BERK. ET BR. 275
R. N. Hilton

See back cover for details of subscription, and prior issues. Publication is irregular, the volume being completed when a convenient number of pages is reached.

Price three dollars

Defoliation of Hevea brasiliensis by Aerial Spraying

F. W. HUTCHISON

Report on an investigation into the possibility of aircraft spraying to defoliate rubber trees as a method of eradicating an outbreak of South American leaf blight.

ALTSON (1950) DREW ATTENTION TO THE SERIOUS CONSEQUENCES attendant on the introduction of South American leaf blight into Malaya, a risk enhanced by the ever increasing speed and scope of international air transport, and put forward suggestions as to the method of eradication which might be used should for any reason plant import and health regulations fail to exclude the disease.

Ordinary methods of disease control would be quite inadequate to deal with an outbreak of South American leaf blight. Isolation of the outbreak and eradication of the disease should be attempted. The success of even such drastic control measures would however, depend on the promptitude with which the outbreak was discovered, on the efficiency of the method of eradication, and, equally important, on the speed with which the method could be put into operation.

The eradication of diseased nursery plants would present no great difficulty, but mature trees present quite a different problem. None of the accepted methods of tree eradication are suitable being laborious and slow acting. As the disease attacks the leaves, the best alternative appears to be the application to the leaves of a defoliant. At once the practical difficulty arises of applying such materials to the trees, the canopy of which could be eighty feet in height. Spraying from the ground would not be feasible and for this reason ALTSON (1950) put forward the suggestion that destructive spraying from the air would appear to offer the greatest chance of success in eradicating the disease in mature areas.

Following on this suggestion, work was put in hand early in 1950 to search for a suitable defoliant and to consider the practical aspects of aerial spraying.

Summarised reports of the experimental work on the selection of the normal butyl ester of 2,4,5-T as a suitable defoliant have been published in the annual *Reports* of the Pathological Division of the Rubber Research Institute of Malaya for 1950 and 1951. A brief summary of the work up to 1953 has been published (HUTCHISON 1955) and a fuller account is included in a review of South American leaf blight (HILTON 1955a).

The present report describes the search for a suitable herbicide and a method of applying it by aerial spraying — work which eventually led to the scheme for an eradicant campaign put forward by the Pathological Division (HILTON 1955b).

Although spraying crops from the air is by no means a new technique, our problem was basically different from such operations insofar as the material to be applied was not a harmless insecticide but a herbicide which, owing to its known toxicity to other crops could cause considerable damage by drift from the target area. For this reason, therefore, careful consideration had to be given to the whole operation; to the choice of aircraft itself and to the performance of the spray equipment.

COMMUNICATION 322

INVESTIGATIONS

The investigations were first directed to a search for a suitable defoliant, during the period 1950-51. This was followed during the first half of 1952 by assessment and calibration tests of the spraying equipment, in the laboratory and in the field. The first field applications were made later in the same year.

Having established the practicability of defoliation by aerial spraying, consideration was given to improving the method, and modified equipment was obtained, in 1953. Although this was fitted to the aircraft and given preliminary calibration runs late in that year, lack of funds prevented any further work being undertaken until 1955. In 1955, calibration experiments were followed by aerial applications to mature rubber.

Experimental Work with Defoliants

At first, the eradication of nursery plants and mature trees had been considered as two separate operations. For the former it was thought that destruction could best be achieved by the use of flame throwers, a parallel case being the eradication of citrus canker from the Gulf States of America. It soon became apparent, after a trial with flame throwers, that destruction of plants by this method was impracticable; therefore, the destruction of both nursery plants and mature trees was considered in the same way. Attention was turned to the use of defoliants, in the first instance to water soluble materials but later to materials dissolved in oil.

The choice of materials that can be used in an aerial spraying programme is restricted. They should be non-poisonous to humans, non-corrosive, lest they damage the aircraft, and store well. Another property, desirable although not essential, is that the material should be selective in its action, so that damage to other crops will be minimised. More important, it should be translocated within the plant to compensate for uneven coverage when using comparatively large drops and small quantities.

The first stage in the work with defoliants was concerned with tests of materials applied as solutions, emulsions or dispersions in water. The materials originally tested included those which were defoliants only, quickly killing the leaves, but these were later discarded in preference to the hormone type herbicides which, in addition to defoliating, considerably delayed refoliation of treated plants. Such materials also have the advantage of being translocated within the plant.

In the second stage, oil soluble formulations of the hormone type herbicides were used, oil having advantages as a carrier for aerial spraying.

Screening of compounds—In the first series of tests (Table I group 1) applications were made with a knapsack sprayer to hevea seedlings 8 - 12 feet high in plots of $\frac{1}{60}$ acre. None of the materials showed much promise in preventing refoliation with the exception of Fernoxone (80% sodium salt of 2,4-D). The addition of the wetting agents, Teepol and Lissapol N did not lead to any better results. Of the compounds tested, Fixanol V.R. (tetradecyl pyridinium bromide) and Lotemcide (60% tar acid) produced the most rapid defoliation but all treated seedlings were refoliating within two weeks. Lotemcide was objectionable to use. Ammate (ammonium sulphamate) and Fernoxone showed some promise in that dieback followed their application.

The addition of the wetting agents Teepol and Lissapol N increased the amount of scorch but reduced leaf fall except with Lotemcide and Rotdoom C (sodium pentachlorphenate).

In the second series of tests (Table I group 2) water dispersible formulations of 2,4-D and 2,4,5-T were outstanding, resulting in complete defoliation of year-old

seedlings within ten days, accompanied by bleeding and dieback. Refoliation was slow and incomplete. It took about four weeks, however, before there was any sign of refoliation. On the other hand, plants treated with sodium pentachlorphenate dropped only those leaves which had been well covered during spraying, and they refoliated normally. Refoliation was only slightly retarded in the seedlings treated with the sodium salt of 2,4,5-T and the n-butyl ester of M.C.P.A. The 37% acid equivalent n-butyl ester of 2,4,5-T gave the best result, treated plants bleeding heavily and dieback becoming extensive in nine days. The 30% acid equivalent n-butyl ester of 2,4-D was a little less effective.

A comparison was made of three oils as carriers: a gas oil (Shell Diesoline) a penetrating oil (Mobil P.O.) and a high aromatic oil (P.Y. Sovacide) — to determine their phytotoxic effects. It was important to establish that the oils were not sufficiently toxic to cause leaf fall before the defoliant was fully translocated. No marked effects resulted, but the penetrating and aromatic oils caused defoliation of the young leaves, while only marginal scorch resulted from the application of gas oil. There was no permanent injury from any of these applications. It was decided to use the gas oil as solvent in the later trials.

The third series of tests (Table I group 3) included only the normal butyl esters of 2,4-D and 2,4,5-T, pentachlorphenol, and three carrier oils, applied to year-old seedlings with a low volume nozzle. Plants treated with pentachlorphenol shed their leaves more rapidly than those treated with the esters but the results were patchy owing to poor spray coverage. Slight dieback of plants treated with pentachlorphenol occurred but refoliation was complete except for those green shoots which had died back. It was evident from this trial that the n-butyl ester of 2,4,5-T was most effective although it induced defoliation more slowly than 2,4-D and much more slowly than pentachlorphenol. There was no consistent effect attributable to the carrier oil, nor to the concentration of the ester.

In the fourth series of tests, again using year-old seedlings and low volume nozzle, (Table I group 4) a mixture of 5% n-butyl 2,4-D and 5% n-butyl 2,4,5-T was applied in each of three carrier oils. No benefit was conferred by the addition of 2,4-D and the result was comparable with that obtained with 2,4,5-T alone. Many of the treated plants died, and what refoliation took place did not start until six weeks after treatment.

Pot experiments with defoliants—Until 1951 the preliminary assessment of the suitability of various materials as defoliants had been carried out in nurseries. It appeared desirable to check the results by a more precise assessment. Applications were therefore made to young potted seedlings under standardised conditions. Pot plants were inserted into a specially designed tower in which they were sprayed with the test solution at the rate of 1 ml per plant. Spraying in the tower was so arranged that only the leaves and stem of the seedling were exposed to the spray, the soil in the pots being covered. Immediately after spraying in the laboratory the plants were returned to the open.

a Nursery trials had established the superiority of the phenoxyacetic acids 2,4-D and 2,4,5-T as defoliants, the latter being the more effective, and a closer examination of these two compounds was desirable. Each of the n-butyl esters was therefore applied to duplicate plants at four concentrations: 1.0%, 0.5%. 0.25%, and 0.125%, in four solvents.

TABLE I. MATERIALS USED IN PRELIMINARY SCREENING TESTS AND THEIR EFFECT ON SEEDLINGS IN THE FIELD

	Material		Concentration % in water	Rate of application gal/acre	Time (days) taken for: scorch	Time (days) taken for: leaf fall	Dieback	Defoliation	Refoliation
	Group 1								
1	Lotemcide (60% tar acid)		10.0	100	> 1	2 — 4	–	good	In this group all treated plants refoliated within about 14 days with the exception of 16, 17, 18, 19 and 20 in which the refoliation was not great until about 21 days.
2			10.0	60	> 1	2 — 4	–		
3		+ Teepol (0.1%)	10.0	60	> 1	4 — 8	+		
4		+ Lissapol N (0.1%)	10.0	60	> 1	4 — 8	+		
5	Sodium chlorate		2.5	100	1 — 2	4 — 8	–	poor	
6			5.0	100	1 — 2	4 — 8	–		
7			10.0	100	1 — 2	4 — 6	–	good	
8		+ Teepol (0.1%)	5.0	60	2 — 4	4 — 6	–		
9		+ Lissapol N (0.1%)	5.0	60	2 — 4	6	–		
10			10.0	60	2 — 3	4 — 6	–	very good	
11		+ Teepol (0.1%)	10.0	60	2 — 3	4 — 6	+	good	
12		+ Lissapol N (0.1%)	10.0	60	2 — 4	4 — 6	–		
13	Sodium dinitro-orthocresolate		2.5	100	1 — 2	3 — 4	–	very good	
14			5.0	100	1 — 2	3 — 4	–		
15			10.0	100	1 — 2	3 — 4	–		
16	Fernoxone (80% salt 2,4-D)		2.5	100	1 — 2	10 — 14	+	good	
17			5.0	100	1 — 2	10 — 14	+		
18			5.0	60	2 — 4	10 — 15	+		
19		+ Teepol (0.1%)	5.0	60	2 — 3	4 — 15	+	poor	
20		+ Lissapol N (0.1%)	5.0	60	2 — 3	5 — 15	+	very good	
21	Fixanol V.R. (tetradecyl pyridinium bromide)		2.5	100	1 — 2	2 — 5	–	poor	
22			5.0	100	1 — 2	2 — 5	–	good	
23			10.0	100	1 — 2	2 — 4	–		
24			5.0	60	2	4 — 6	–	very good	
25			10.0	60	1 — 2	4 — 6	–		
26	Ammate (ammonium sulphamate)		5.0	100	1 — 2	3 — 4	+	good	
27			10.0	100	1 — 2	3 — 7	+		
28	Rotdoom C (pentachlorphenate)		1.25	60	1 — 3	3 — 6	+		
29		+ Teepol (0.1%)	1.25	60	1 — 3	3 — 6	+		
30		+ Lissapol N (0.1%)	1.25	60	1 — 2	4 — 6	+		

	Group 2							
31	2,4-D (n-butyl ester 30% acid equiv)	5 lb ae/ac	50	3 — 4	3 — 10	++	complete	None within 4 weeks
32	2,4,5-T (n-butyl ester 37% acid equiv)	5 lb ae/ac	50	3 — 5	3 — 10	++		
33	M.C.P.A. (n-butyl ester 50% acid equiv)	5 lb ae/ac		6 — 8	10 — 15	+	poor	Slight delay
34	Santobrite (sod. pentachlorphenate)	10.0	50	7	4 — 8	−		No delay
35	2,4,5-T (sod. salt)	5 lb/acre	50	6	9 — 12	+	good	Slight delay
			50					
	Group 3	*						
36	2,4-D (n-butyl ester 80% acid equiv)	5 lb ae/ac (1)	5	1 — 3	7 — 12	+	complete	30% refoliation only after 1½ months
37		5 lb ae/ac (2)	5	1 — 3	7 — 12	+		
38		5 lb ae/ac (3)	5	1 — 3	7 — 12	+		
39		1 lb ae/ac (1)	5	1 — 3	7 — 12	+		
40		1 lb ae/ac (2)	5	1 — 3	7 — 12	+		
41		1 lb ae/ac (3)	5	1 — 3	7 — 12	+		
42	2,4,5-T (n-butyl ester 80% acid equiv)	5 lb ae/ac (1)	5	1 — 3	7 — 17	+		No refoliation up to 1½ months
43		5 lb ae/ac (2)	5	1 — 3	7 — 17	+		
44		5 lb ae/ac (3)	5	1 — 3	7 — 17	+		
45		1 lb ae/ac (1)	5	1 — 3	7 — 17	+		
46		1 lb ae/ac (2)	5	1 — 3	7 — 17	+		
47		1 lb ae/ac (3)	5	1 — 3	7 — 17	+		
48	Pentachlorphenol	20 (1)	5	1 — 4	3 — 10	+	poor	No delay
49		20 (2)	5	1 — 4	3 — 10	+		
50		20 (3)	5	2 — 6	3 — 10	+		
51		10 (1)	5	1 — 3	3 — 10	+		
52		10 (2)	5	1 — 3	3 — 10	+		
53		10 (3)	5	1 — 3	3 — 10	+		
	Group 4							
54	5% 2,4-D + 5% 2,4,5-T (n-butyl esters)	(1)	5	3 — 5	5 — 17	++	poor	Only very slight refoliation at 4 months
55		(2)	5	3 — 5	5 — 17	++		
56		(3)	5	3 — 5	5 — 17	++		

* In groups 3 and 4 oils were used as solvents as follows:
(1) = PY Sovacide
(2) = Shell Diesoline
(3) = Mobil Penetrating Oil

Extent of dieback: − = nil
+ = present
++ = more extreme

TABLE 2. EFFECT OF N-BUTYL ESTERS OF 2,4,5-T AND 2,4-D IN FOUR SOLVENTS, ON POTTED SEEDLINGS

Solvent	2,4,5-T	2,4-D
Shell Diesoline	Epinasty in 1 day. General discolouration in all concentrations in 24 hours. All leaves dead in 9 days. Slight leaf fall before 17 days. All plants dead 2 months later.	Epinasty in 20 hours. General discolouration in 1 day. Leaves dead in 4 days but little death at 0.25 and 0.125%. Leaf fall little before 17 days. Refoliation at 1 month except one plant at 1% which died at 2 months.
Mobil Penetrating Oil	Epinasty in 1 day. Discolouration in 4 days but slight at concentrations of 0.25 and 0.125%. All leaves dead in 14 days except two low concentrations. Slight leaf fall before 17 days. All plants dead 2 months later except at 0.25 and 0.125%.	No epinasty. Discolouration in 1% at 1 day but others slight. Leaf fall slight in all concentrations by 17 days. Refoliation in 1 month. One plant dead at 2 months at 1%.
Shell Aromatic Gas Oil	Epinasty in 1 day. Discolouration in 1 day. All leaves dead in 9 days. Slight leaf fall before 17 days. All plants dead 2 months later.	No epinasty. Discolouration in 1 day but damage slight at two lower concentrations. Slight defoliation only and growth little affected. Only one plant dead at 1% at 2 months.
P.Y. Sovacide	Epinasty in 20 hours. Discolouration in 8 hours. Leaves dead in 5 days except one plant at 0.5 and 0.25%. Slight leaf fall before 17 days. All plants dead 2 months later.	Epinasty in 1 day. Discolouration in 1 day. Leaves dead in 5 days and leaf fall in 7. Damage slight and refoliation in 14 days. One plant dead at 2 months at 1% and 0.25%.

The results tabulated in Table 2, confirm the superiority of 2,4,5-T over 2,4-D. All but two of the thirtytwo seedlings treated with 2,4,5-T were dead in two months, whereas all but five of the 2,4-D treated plants were still alive at that time. In general, symptoms of injury appeared earlier in the 2,4,5-T treated plants when P. Y. Sovacide was used as the solvent but the ultimate result appeared to be little influenced by the type of oil used.

b The non-volatile beta-butoxyethyl esters of 2,4-D and 2,4,5-T were compared with the n-butyl esters as it was thought that perhaps less danger of unwanted damage would result from their use. They were applied to pairs of potted seedlings at concentrations of 2%, 1%, 0.5%, 0.25% and 0.1%. For comparison other plants were treated with the n-butyl esters of 2,4-D and 2,4,5-T.

Both the n-butyl and beta-butoxyethyl esters of 2,4,5-T were more phytotoxic than the 2,4-D ester but, whereas the n-butyl ester of 2,4,5-T killed more quickly than the non-volatile ester, the result was the reverse with 2,4-D. All concentrations of the n-butyl ester of 2,4,5-T killed the seedlings in six weeks, and in seven weeks with the beta-butoxyethyl ester. With the beta-butoxyethyl ester of 2,4-D, only the three highest concentrations killed the seedlings (seven weeks). Seedlings treated with lower concentrations refoliated. Only one plant treated with 1%, two with 0.5% and two with 0.1% were killed by the n-butyl ester of 2,4-D. It was concluded that neither of the non-volatile esters was as an effective defoliant as the n-butyl ester of 2,4,5-T.

c The following compounds also were tested for their herbicidal value but were found to be less effective than the n-butyl ester of 2,4,5-T.

1 n-butyl 4-chlorophenoxyacetate
2 3,6-endoxotetrahydrophthalic acid
3 disodium 3,6-endoxohexahydrophthalate

Although they all effectively defoliated the seedlings to which they were applied, only 3,6-endoxotetrahydrophthalic acid caused any inhibition of refoliation.

Choice of defoliant—Nursery trials having indicated, and the pot experiments confirmed the superiority of n-butyl 2,4,5-T as a defoliant, trials continued with this material only. The gas oil (Shell Diesoline) was selected as a carrier on account of its ready availability and low cost.

Effect of pentachlorphenol on solutions of n-butyl 2,4,5-T—As the object of this work on herbicide was to select a material which could be used to check the spread of South American leaf blight by defoliating an infected area, and as 2,4,5-T is not fungicidal, the desirability of adding a fungicide to the solution was considered. Pentachlorphenol was suggested.

The presence of pentachlorphenol in solution with the 2,4,5-T had, however, been shown in nursery trials to increase the rate of defoliation. It was thought that the leaves might fall before the hormone was fully translocated. Experiments were therefore carried out to determine the maximum concentration of pentachlorphenol that could be incorporated in 2,4,5-T solutions without reducing their herbicidal activity.

Two concentrations of n-butyl 2,4,5-T (2% and 0.2%) in solution in Shell Diesoline with the addition of pentachlorphenol at four concentrations (10%, 5%, 2.5% and 1.25%) were applied to duplicate potted seedlings, the rate of application being the standard 1 ml per plant.

In the solutions with the higher concentration of 2,4,5-T (2%) the results showed no difference between the concentrations of pentachlorphenol, with the exception of the highest (10%). In this case it would appear to indicate that death of the leaves had taken place before the herbicide had been fully translocated. The results obtained with the low concentrations of 2,4,5-T (0.2%) were erratic but indicated that all concentrations of pentachlorphenol were having an adverse effect on the ultimate result.

To verify this, reduced concentrations of pentachlorphenol were tried in solution with 2% and 0.2% 2,4,5-T. Pentachlorphenol was added to the solutions at the rate of 1%, 0.5%, 0.1%, 0.05% and 0.01%. All the solutions caused defoliation in twelve days, irrespective of the 2,4,5-T or pentachlorphenol concentration. However, 2,4,5-T alone took a few days longer to bring about defoliation (fifteen days). The low concentration of 2,4,5-T (0.2%) combined with the whole range of concentrations of pentachlorphenol killed the plants more slowly than the high concentration (2.0%) and with both concentrations of 2,4,5-T without pentachlorphenol. It was also established that there was definite deterioration in final results with 0.2%, 2,4,5-T combined with concentrations of pentachlorphenol in excess of 0.05%. With 2.0% 2,4,5-T on the other hand, 0.5% pentachlorphenol appeared to mark the limit.

It was at this time that consideration was given to the advantage of making a separate application of pentachlorphenol following 2,4,5-T. In this way a higher concentration

of the fungicide could be applied without reducing the amount or rate of refoliation. An experiment was therefore carried out to secure information as a guide to the period which should be allowed to elapse between the separate applications of the defoliant and pentachlorphenol, to be certain that leaves were not defoliated by the latter before the 2,4,5-T had been translocated. Year-old seedlings in the nursery were treated with n-butyl 2,4,5-T by applying 0.2 ml of a 10% solution to the lowest leaf on the plant, from a micro-syringe. Treated leaflets were removed from duplicate plants in each treatment by cutting them from their petioles at intervals of 1, 2, 4, 8, 16 and 32 hours and 2, 4, and 6 days. Rain fell 10 hours after treatment. No treated leaves were left on the plants after six days.

The results were erratic. While some plants defoliated completely, others lost only a few leaves. In every case, however, it was clear that translocation of the 2,4,5-T from the treated leaves took place rapidly. All plants except those from which the leaves were removed after one hour showed symptoms in untreated leaves and the growing tip, within two days. It was therefore decided that an application of the fungicide pentachlorphenol could be given on the day following the defoliant without in any way endangering the uptake of the 2,4,5-T.

Aircraft and Equipment

In 1950 discussions were initiated by C. E. T. Mann, Director of this Institute, and R. A. Altson, Head of the Pathological Division, with the Colonial Insecticides, Fungicides, and Herbicides Committee in London, and the Ministry of Supply Chemical Defence Experimental Establishment at Porton with a view to deciding on a suitable aircraft and spraying equipment. Porton suggested the use of a Dakota as this type was available locally and also possessed a good load carrying ability. It was further suggested that the emission pipe designed at Porton for the Anson, and used successfully in East Africa against desert locusts, could be modified for use with the Dakota. The use of helicopters was discussed but the idea was not pursued because such aircraft were not available locally at the time; operation and maintenance costs are high, moreover, their load carrying capacity in the tropics is low.

Following further discussions in this country with the Department of Civil Aviation, the Royal Air Force, and Malayan Airways, it was decided that the Porton technique of relatively high level spraying could not be considered owing to the risk of damage to adjacent areas by spray drift. It was decided that an aircraft fitted with boom and nozzles, and flying just above tree-top height, should be used for the experiments. This obviously excluded as large an aircraft as the Dakota, which through lack of manoeuvrability at low speeds would become highly hazardous to operate at the required height over anything but level country. Moreover, the number of airstrips in Malaya from which such aircraft could operate was limited. On a suggestion, therefore, of the Director of Civil Aviation it was agreed that an approach be made to Government to lend us for our experimental work one of the de Havilland DHC 3 Beavers which had recently been obtained for 'feeder' services. Permission was granted by Government in 1952 for the hire of one of these aircraft. Spraying equipment which had already been designed for the Beaver by de Havillands was obtained from Canada.

The de Havilland Beaver was designed and built in Canada as a general-purpose aircraft. Its economical operation coupled with good pay load, low stalling speed and easy manoeuvrability, made it ideal for our work.

When the Beaver is modified for spraying the seats are removed from the aircraft to allow positioning of the 200 gallon tank across the cabin, the passenger door being removed also to allow the ends of the tank to be flush with the sides of the fuselage (*Figure 1*). The tank contained an electrically driven pump which, operating at a pressure of 20 lb per square inch, had a maximum output of 12 gallons per minute. The control assembly consists of operating solenoid and relays, pressure gauge and regulating valve, and is conveniently situated on the floor at the right hand of the pilot, the operating off/on switch being attached to the control column.

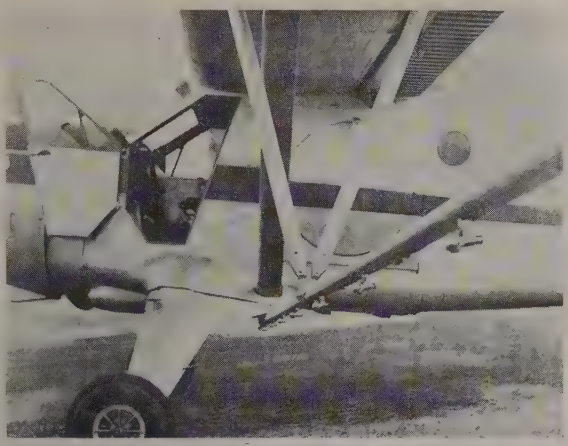


Figure 1. Beaver fitted with 200 gallon tank, boom and nozzles.

The spray boom, 48 feet in length, contains nineteen nozzles and is suspended by struts from the wings. The nozzles have interchangeable orifices and for our experiments were additionally fitted with diaphragm control valve to check drip. The complete spray equipment weighed 177lb. It is claimed by the manufacturers that with a full tank (240 U.S. gallons) 240 acres can be sprayed in 20 minutes at the rate of one U.S. gallon per acre. This equipment was used in the original field applications in 1952, the spray boom being fitted with Whirljet $\frac{1}{8}$ inch B5 nozzles with No. 3 ($\frac{3}{32}$ inch orifice diameter) nozzle caps, and diaphragm check valves (No. 4666). Output from this gear was insufficient to meet the range required in our experiments, but the maximum output of the pump would not feed larger nozzles.

Figure 2. The Simplex wind driven pump seen mounted below the fuselage.

In 1953 the immersion pump was removed and an external wind driven pump fitted — the Simplex, manufactured by Columbia Exporters Incorporation of Oregon (*Figure 2*). This had an output of 28 gallons per minute, sufficient to supply No. 10 nozzles which had an orifice diameter of $\frac{3}{16}$ inch. However, the mounting position of this pump, beneath the fuselage, caused considerable vibration through propeller wash and the mountings continually fractured. Tests with this pump were therefore considerably restricted.

With the production of a rotary brush spraying gear for the Beaver by the Independent Crop Dusting Incorporation, one of the units — known as the I.C.D. G-Whizzer was purchased in 1953. This consists of a short boom to either end of which is attached a wind driven fan which drives a series of round plate-like wire brushes to which the spray fluid is fed by gravity. *Figure* 3 shows the aircraft fitted with this unit. The spray solution flows to the tips of the wires from which it is centrifugally ejected. Both dosage and drop size can be varied by altering the speed of the brushes, the wire diameter, the brush diameter, the number of wires discharging particles, and the rate of feed of solution to the brushes. Using a given brush specification, as the speed drops the average particle size will increase. The control of drop size and volume with this type of equipment is very great.

Figure 3. General view of the Beaver fitted with rotary brush I.C.D. spraying equipment.

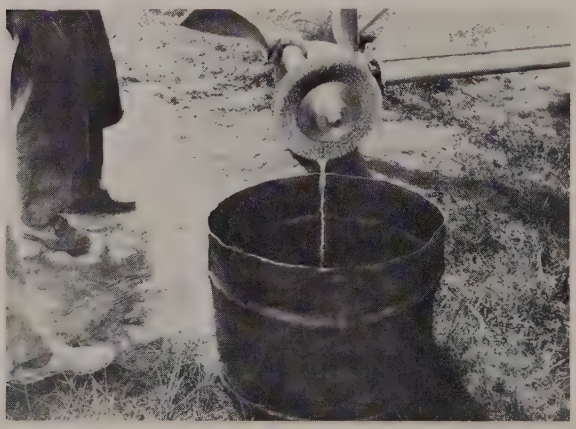


Figure 4. Details of the I.C.D. rotary brush showing wind driven fan and wire brushes.

For our particular requirements two Series 800 units were used, operated with fans of 50° pitch each driving four 10 inch wire brushes. The wire diameter composing the brushes was 0.014 inch and there are approximately 2,500 wires in a brush of this type. The 50° pitch fans were estimated to operate the brushes at 1200-1500 r.p.m. at an air speed of 90 m.p.h. This set-up gave a maximum output of 43.5 gallons per minute, equivalent at 90 m.p.h. and a swathe of 66 feet, to approximately 3.6 gallons per acre. *Figure 4* shows the details of one of the rotors.

Communications and Markers

Communications—The success of any aerial spraying operation depends to a large extent on contact between the controlling party on the ground and the aircraft. Communication between ground parties is also highly desirable. Without radio communication between the ground party and aircraft the transmission of a simple change in procedure to the pilot, once the aircraft has left the ground, can be quite a major task

with no guarantee that the directions have been fully understood. Early in our consideration of the aerial spraying problem the need for radio communication was appreciated and, in consultation with the Department of Telecommunications, it was suggested that a V.H.F. radio-telephone unit would meet our requirements for air/ground communication. Accordingly a Pye V.H.F. 15 watt radio-telephone, type P.T.C. 115, was purchased and operated on a frequency of 131.9 megacycles.

The transmitter/receiver unit was built into a Land Rover, the front centre seat being removed to accommodate it, and operated from the electrical circuit of the vehicle (*Figure 5*). Consideration had been given to operating the set from batteries but it was felt that the slight gain in mobility would be more than offset by the inconvenience of having the large batteries recharged and transported in the field.

Figure 5. Pye P.T.C.115 radio-telephone fitted into Land Rover.

Two aerials were available for use, a quarter wave vertical aerial mounted on the vehicle, and a quarter wave Unipole aerial on a 120 feet feeder. It was intended to use the latter mounted on a pole above the tree tops, but the performance of the set when using the vehicle aerial was so satisfactory, even under a canopy of trees, that it was used throughout. Operating in this manner it was possible to maintain contact with the aircraft from our calibration spraying site at Port Swettenham airstrip to its base at Kuala Lumpur, a distance of approximately 20 miles. The completely satisfactory functioning of the radio-telephone unit, even under very rough conditions, simplified the work of controlling the experiments. At times, long and detailed directions were transmitted to the pilot without difficulty.

Ground communication presented a much more considerable problem, especially in hilly country. A number of portable transmitter/receivers were tried, operating both on the H.F. and V.H.F. frequencies. It was apparent that H.F. frequencies were much more satisfactory and finally military 68-T sets were used, operating on a frequency of 3.5 megacycles. It was considered advisable to control ground parties on a frequency different from that used for aircraft control to prevent misinterpretation of directions. Although the ground sets performed satisfactorily over distances of 2 to 3 miles, which was sufficient for our spraying operations, they were cumbersome and in difficult country were troublesome to transport.

More easily portable apparatus have recently appeared on the market but these have not been tried.

Markers—Little information on suitable methods of delimiting areas for treatment could be found in the literature. The marking of spray runs in field crop or locust spraying does not have to contend with the problem encountered in spraying tree crops—that the ground is rarely visible from the air, and therefore, markers used have to be placed, or penetrate, above the canopy of the trees.

Three methods of marking appeared worth testing in the field, namely: balloons, smoke and Verey signals.

a Balloons—the use of hydrogen filled balloons constituted an obvious choice. On the advice of the Meteorological Officer, meteorological sounding balloons were tried. Both the 350 and 100 gm balloons proved suitable but it was found that the former, being larger in size, could be used quite under-inflated giving them longer life with less likelihood of puncture in penetrating the branches of the trees. Balloons were eventually used as markers in the spraying operations but their disadvantages were (*i*) difficulty in coaxing them through the canopy at the exact spot required; (*ii*) even greater difficulty in retrieving them after spray runs; (*iii*) continued trouble with tangled and knotted lines at critical moments; (*iv*) the need to transport hydrogen cylinders; (*v*) the necessity of placing the balloons in position before the actual operation if the aircraft was not to be delayed between spray runs; (*vi*) rather short a life on exposure to the tropical sun and oil sprays.

b Smoke—orange coloured smoke generators were tried but the method proved quite useless as the smoke cloud did not penetrate the canopy. This method was abandoned except to indicate wind direction and strength.

c Verey signals—it was considered that, if some type of rocket or flare could be fired vertically into the air at either end of the spray run, the pilot would have a signal of sufficient duration on which to line up his aircraft. It was with this in mind that Verey signals were given a trial; furthermore, they appeared to offer a simple and expedient procedure. Trials with this method, even when using ground to ground radio communication, however, showed little promise of success and there was a risk of starting ground fires from the falling cartridges. Furthermore, at the time when the pilot's attention was fully occupied in bringing the aircraft to the correct height and speed, the concentration required to catch sight of the momentary smoke trail before it drifted off course had an adverse effect on the other operations. The method was therefore abandoned.

Calibration and Assessment Trials

Before undertaking field applications it was necessary to assess the performance of the apparatus as the suppliers were unable to supply data on drop diameter, which largely determines the effective performance of such equipment. Assessment trials were planned to measure the range of drop sizes, in addition to swathe width, to arrive at the best aircraft flying speed and height of operation. It should be understood that the experiments recorded below were not aimed at studying all the aspects of aerial spraying but only to assess the suitability of the equipment and to work out a method of applying the defoliant.

The spray produced was assessed by a method recommended by the Chemical Defence Experimental Establishment, Porton, in which the drops were caught on filter paper and their diameters measured.

Stain/drop size relation—For calibration, drops were produced from a microburette, following the method described by Lane (1947), and collected on Whatman's No. 1 filter paper, which was to constitute the facing of the sampling envelopes used in the field. A 1% solution of Waxoline Red dye in Shell Diesoline was used. By increasing

or decreasing the supply of air to the nozzle in the microburette drop size could be varied. The diameter of the drops was calculated from their weight. A check on the calculated drop size was made by catching them in 95% ethyl alcohol and measuring under the microscope. At the same time, drops were also collected on the filter paper where they were allowed to dry in the laboratory for four hours before the spread was measured. The arbitrary period of four hours was chosen as being approximately the time which would elapse in field assessment trails between collection of the drops and their later measurement or recording in the laboratory. The relationship between stain diameter and drop size is graphically represented in *Figure 6*. The assessment of trials carried out in 1952 was made on this relationship. In trials carried out after 1952 a change in the facing paper to Green's No. 401 entailed a re-assessment of the stain/drop relation and the new relationship is indicated in *Figure 7*. Examination of stains collected on papers at humidities of 30, 50, 60, 70 and 90% R.H. showed that with the exception of the highest humidity the variation in stain diameter was within the limits of error in measuring individual stains and could therefore be ignored over the range of humidities obtaining during our experiments.

Estimation of drop size, ground recovery and swathe width—Experiments were carried out on an airstrip at Port Swettenham where the macadamed surface and absence of other aircraft made an ideal site. Assessment runs were made soon after dawn and were completed before 9.30 a.m. by which time convection was beginning. Wind was never absent during these early hours, but it was light.

The method of assessment used was basically one that had been outlined for us by the Ministry of Supply Chemical Defence Experimental Establishment. It consisted of catching the spray drops on sampling envelopes measuring 9 inches x 10 inches disposed on the ground at intervals downwind of the aircraft track, then counting the drops and measuring their diameter.

In the assessment trials the sampling envelopes were placed close together in the rows at the up-wind end and wider apart downwind. Rows of papers were 100 yards apart across the line of flight. Details of the spacing in the rows are given under the trial headings.

Although the spraying oil (Shell Diesoline) was dyed with 1% Waxoline Red to make the drops more easily counted and measured, some difficulty was experienced in assessing the smaller drops unless they were counted immediately, because they quickly faded. With the limited staff at our disposal, a more permanent form of recording of the drops collected on the sampling envelopes was necessary.

A satisfactory method of recording the stains photographically was worked out using Kodak Autopositive Document paper. The method consisted of cutting from the sampling envelopes the required sampling area and contact printing this on autopositive document paper in a Kodak Duostat printer. The exposure time being 15 to 20 seconds, and with several samples combined on a 10 inches by 12 inches sheet of photographic paper, the method was rapid. The exposed paper was developed and fixed in the normal manner. The resulting prints, consisting of black 'drops' on a white ground, will keep indefinitely and assessment can be carried out whenever time permits. From 1953 all sampling papers were photographed by this method.

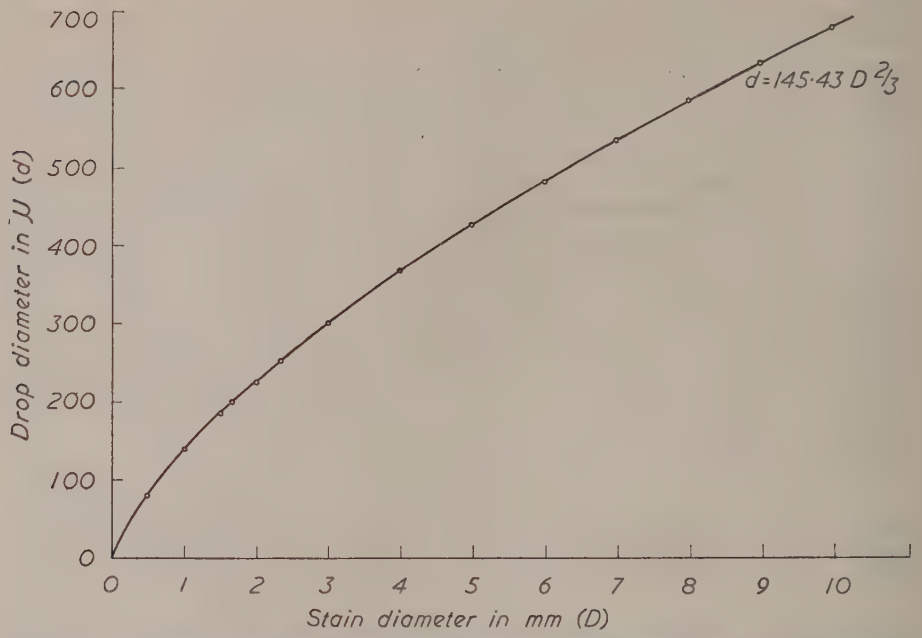


Figure 6. Graph showing relationship between drop diameter and stain diameter on Whatman's No. 1 paper.

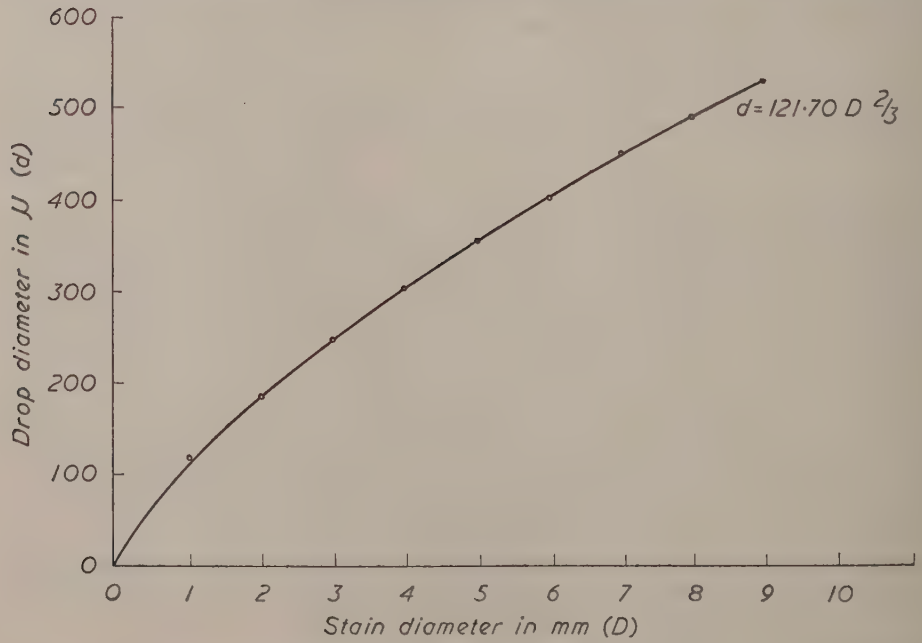


Figure 7. Graph showing relationship between drop diameter and stain diameter on Green's No. 401 paper.

Heavy deposits on many of the sampling papers sometimes made it extremely difficult to measure accurately and count the drops. An attempt was made to catch drops, from spray runs, in a matrix which would contain them individually and prevent evaporation. A satisfactory mixture was obtained as follows: gelatin, 78 gm; glycerin, 520 ml; trimethanolamine, 130 ml; Teepol, 32.5 ml; and water, 1300 ml. In the one field trial in which this mixture was used drops were collected satisfactorily but subsequent melting of the matrix due to high temperature in transport, destroyed all the samples.

One or two low flying runs with the aircraft loaded made it apparent that, under normal flying conditions, which can be rough, a speed less than 90 m.p.h. would allow too small a margin of safety when spraying just above the tree tops. In all the calibration work as well as during field applications an airspeed of 90 m.p.h. was maintained.

Trial 1. Boom fitted with nineteen $\frac{1}{8}$ inch B5 Whirljet nozzles and No. 3 ($\frac{3}{32}$ inch) orifices operated by immersion pump delivering 12 gal/min.

The size of drops produced by the No. 3 orifices, when flying at a speed of 90 m.p.h. was worked out when the aircraft was flying at 60 feet and 250 feet. Saturation of many of the sampling papers when the height was only 30 feet was so intense as to make estimation impossible.

The figures presented in Table 3 (A) and (B), relating to the spray run at a height of 60 feet are based on two sets of sampling papers disposed downwind as indicated in *Figure 8;* those in Table 4 (A) and (B), relating to a run at a height of 250 feet, are based on three (*Figure* 9).

TABLE 3 A. DROP SPECTRUM EXPRESSED AS THE PERCENTAGE OF MATERIAL RECOVERED

Aircraft height — 60 feet.

Drop diameter μ	Percentage recovery	Cumulative percentage
up to 100	0.83	—
101 — 200	15.77	16.60
201 — 300	31.12	47.72
301 — 400	38.17	85.89
401 — 500	14.11	100.00

(*i*) Drop size — Table 3 (A) indicates that the mass median diameter of the spray was 310 μ. Just over 38% of the volume of spray was produced in the drop diameter range 301 to 400 μ and 31% in the range 201 to 300 μ.

(*ii*) Ground recovery — samples were collected over a swathe width of 120 yards. Within the sampling area 77% of the sprayed solution was accounted for.

TABLE 3 B. RECOVERY OF SPRAY DOWNWIND EXPRESSED IN U.S. GALLONS PER ACRE FOR EACH SAMPLING POINT

Aircraft height — 60 feet.

Sampling point	Estimated recovery gallons/acre
1	0.46
2	0.30
3	0.32
4	0.34
5	0.28
6	0.31
7	0.07
8	0.09
9	0.04
10	0.05
11	0.08
12	0.03
13	0.03
14	0.01

(*iii*) Swathe width — *Figure 8* shows the characteristic of the swathe cross section and the comparatively narrow swathe width with any appreciable deposit.

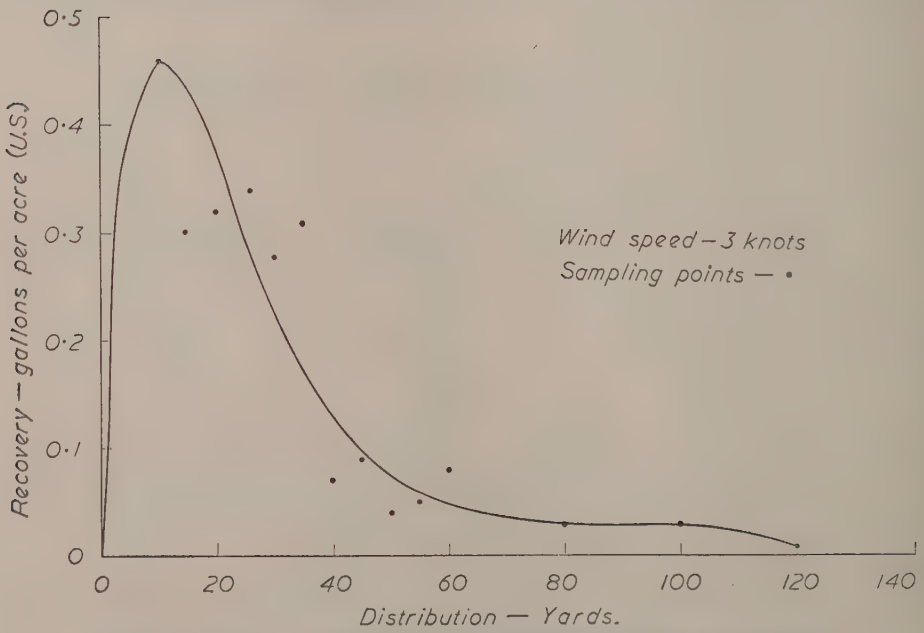


Figure 8 Trial 1. Distribution of spray from aircraft run at 60 feet.

TABLE 4 A. DROP SPECTRUM EXPRESSED AS THE PERCENTAGE OF MATERIAL RECOVERED

Aircraft height — 250 feet.

Drop diameter μ	Percentage recovery	Cumulative percentage
up to 100	trace	—
101 — 200	6.65	6.65
201 — 300	25.95	32.60
301 — 400	37.05	69.65
401 — 500	30.35	100.00

(*i*) Drop size — the mass median diameter, calculated as 340 μ, Table 4 (A), is slightly larger than that recorded in Table 3 (A). This appears to be the result of the larger recovery of drops within the range 401 — 500 μ (30.35% as against 14.11%), but is probably well within the errors of stain size measurement.

(*ii*) Ground recovery — samples were recovered over a swathe of 240 yards and 83% of the sprayed solution was accounted for within the sampling area.

TABLE 4 B. RECOVERY OF SPRAY DOWNWIND EXPRESSED IN U.S. GALLONS/ACRE AT EACH SAMPLING POINT

Aircraft height — 250 feet.

Sampling point	Estimated recovery gallons/acre
1	0.36
2	0.24
3	0.32
4	0.11
5	0.05
6	0.04
7	0.03
8	0.02
9	0.01
10	0.01
11	0.02
12	trace

(*iii*) Swathe width — the higher altitude of application has of course resulted in a wider swathe width (*Figure 9*) and subsequent lower peak contamination.

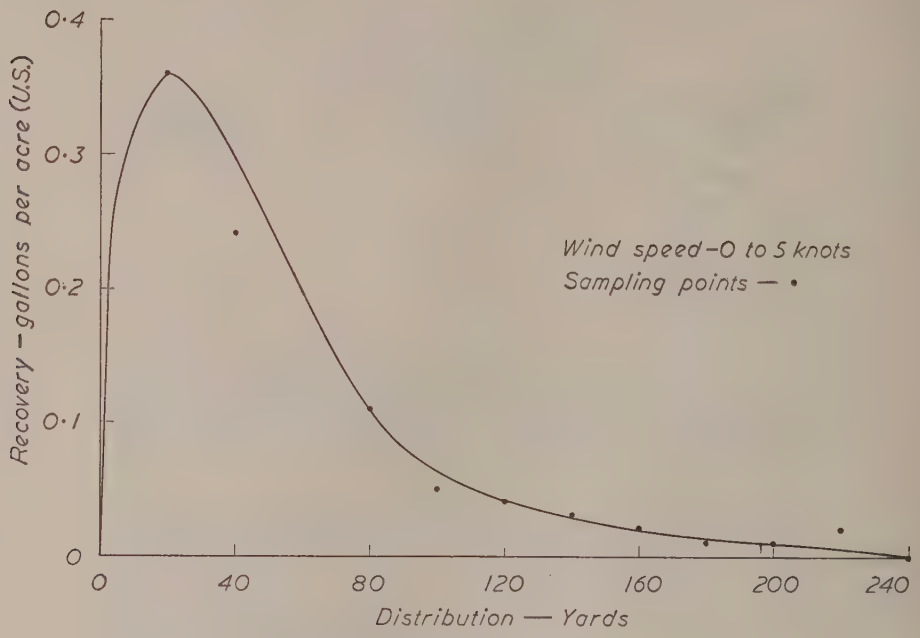


Figure 9 Trial 1. Distribution of spray from aircraft run at 250 feet.

Trial 2 — Boom fitted with nineteen $\frac{1}{8}$ inch B5 Whirljet nozzles and No. 10 ($\frac{3}{16}$ inch) orifices. Operation by external wind driven 1¼ inch Simplex pump delivering a maximum of 28 gallons per minute.

Due to the expected heavier output with the Simplex pump unit it was decided to increase the height of operation to 100 feet, in this way distributing the spray of drops to make assessment easier. In fact this did not occur to any great extent owing to low air movement at the time of application.

The first assessment with this equipment — Table 5 (A) and (B) — in which three rows of sampling papers were distributed downwind at the intervals recorded in *Figure 10* gave a low recovery of drops and a repeat run under the same conditions, of which details are given in Table 6 (A) and (B), gave an even poorer recovery. In part, the poor recovery resulted from the necessity to ignore drops collected on the first sampling envelope in each row which was contaminated with drops which had formed off the spray boom and underside of the aircraft.

TABLE 5 A. FIRST RUN
DROP SPECTRUM EXPRESSED AS THE PERCENTAGE OF MATERIAL RECOVERED

Aircraft height — 100 feet.

Drop diameter μ	Percentage recovery	Cumulative percentage
up to 100	0.50	—
101 — 200	14.95	15.45
201 — 300	22.05	37.50
301 — 400	21.67	59.17
401 — 500	40.83	100.00

(*i*) Drop size — the mass median diameter in Table 5 has been calculated as 340 μ.

(*ii*) Ground recovery — samples were collected over a swathe of 100 yards and within the sampling area 50% of sprayed solution was accounted for. The recovery from one row of papers in this trial was 25% less than in the other two sampling rows. No explanation for this can be given but while it has necessarily affected the percentage recovery it is doubtful if it has had much effect on the recorded drop sizes.

TABLE 5 B. FIRST RUN
RECOVERY OF SPRAY DOWNWIND EXPRESSED IN U.S. GALLONS PER ACRE FOR EACH SAMPLING POINT

Sampling point	Estimated recovery gallons/acre
1	0.29
2	0.67
3	0.52
4	0.51
5	0.40
6	0.17
7	0.14
8	0.17
9	0.14
10	0.05

(*iii*) Swathe width — the spray cloud was collected within a swathe width of 100 yards and its characteristics are illustrated in *Figure 10*.

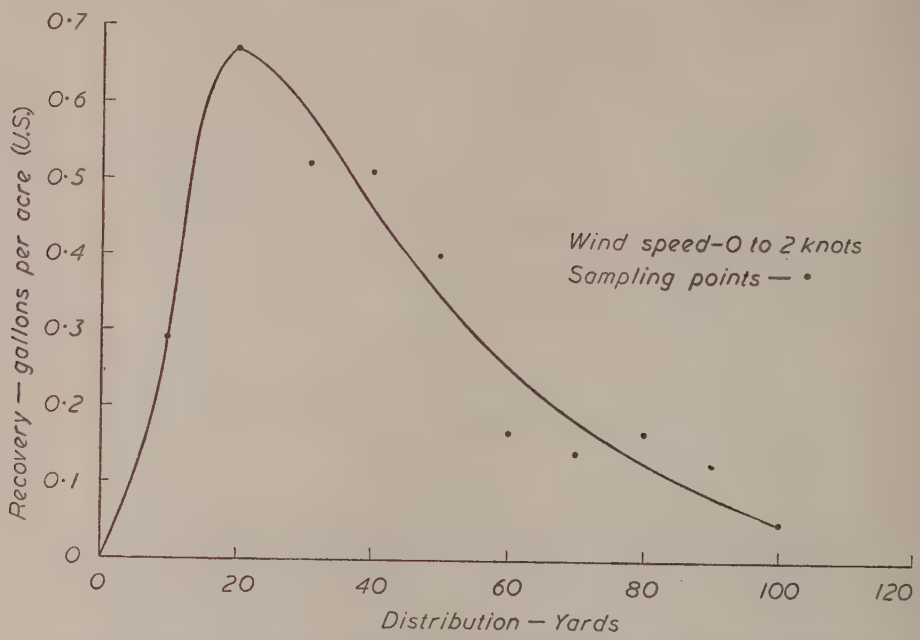


Figure 10 Trial 2. Distribution of spray from aircraft run at 100 feet (1st run).

TABLE 6 A. SECOND RUN
DROP SPECTRUM EXPRESSED AS THE PERCENTAGE OF MATERIAL RECOVERED

Aircraft height — 100 feet.

Drop diameter μ	Percentage recovery	Cumulative percentage
Up to 100	0.30	—
101 — 200	6.38	6.68
201 — 300	21.08	27.76
301 — 400	23.76	51.52
401 — 500	48.48	100.00

(*i*) Drop size — owing to a low recovery of the sprayed solution the figure of 380 μ for mass median diameter is suspect.

(*ii*) Ground recovery — only 45% of the sprayed solution was accounted for within the sampling area. There was a low recovery of drops within the range 101 — 200 μ diameter, only 6.38%, as compared with 14.95% in the first run.'

TABLE 6 B. SECOND RUN
RECOVERY OF SPRAY DOWNWIND EXPRESSED IN U.S. GALLONS/ACRE AT EACH SAMPLING POINT
Aircraft height — 100 feet.

Sampling point	Estimated recovery gallons/acre
1	0.25
2	0.35
3	0.35
4	0.41
5	0.53
6	0.23
7	0.21
8	0.13
9	0.17
10	0.07
11	0.08

(*iii*) Swathe width — the spray was collected over a swathe of 110 yards. (*Figure 11*).

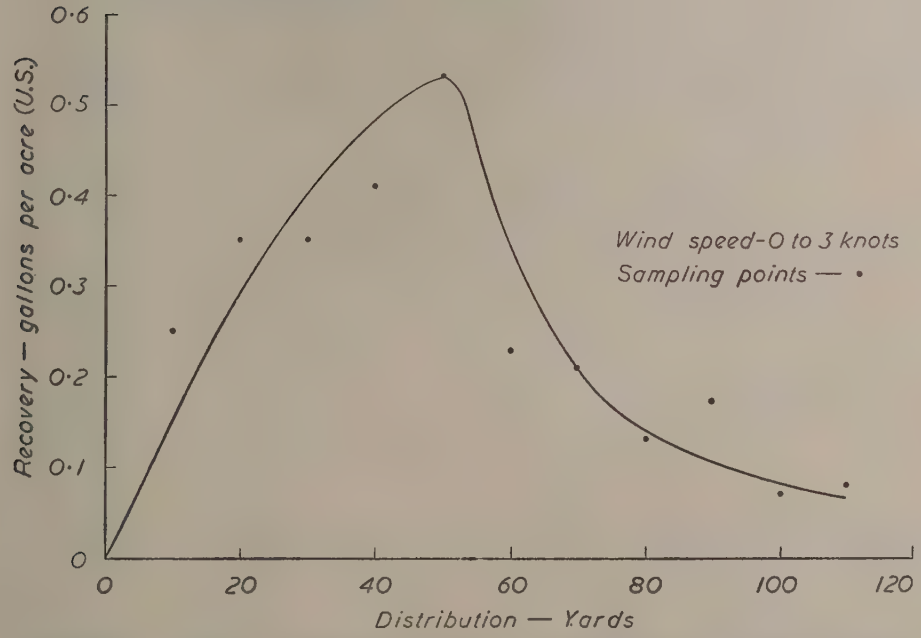


Figure 11. Trial 2. Distribution of spray from aircraft run at 100 feet (2nd run).

Trial 3 — I.C.D. G-Whizzer brush gear fitted with four 10 inch (0.014 diameter wire) brushes. Two rotors were fitted to the aircraft which gave a maximum output of 43.5 gallons per minute at 90 m.p.h.

When operating from 100 feet the contamination of papers was so great with the unit delivering maximum quantity that it was not possible to make an assessment. In the two runs of which details are given below, the output valve was adjusted to give 21 gallons per minute at 90 m.p.h.

In the first run (Table 7) three rows of sampling papers were laid out 100 yards apart with papers within the row as recorded in *Figure 12*, but only two rows were used in the second run (Table 8 and *Figure 13*).

Table 7 A. First Run
Drop Spectrum Expressed as the Percentage of Material Recovered
Aircraft height — 100 feet.

Drop diameter μ.	Percentage recovery	Percentage cumulative
Up to 100	0.35	—
101 — 200	18.46	18.81
201 — 300	55.48	74.29
301 — 400	13.13	87.42
401 — 500	12.58	100.00

(*i*) Drop size — Table 7 (A) gives details of the drop spectrum, the mass median diameter being 250 μ. A striking feature of the drop spectrum is the narrow range of drop sizes with over 55% of them in the range 201 — 300 μ diameter.

(*ii*) Ground recovery — 69% of the sprayed solution was accounted for within the sampling area.

Table 7 B. First Run
Recovery of Spray Downwind Expressed in U.S. Gallons/Acre at each Sampling Point
Aircraft height — 100 feet.

Sampling point	Estimated recovery gallons/acre
1	0.08
2	0.08
3	0.35
4	0.32
5	0.41
6	0.63
7	0.48
8	0.53
9	0.34
10	0.24
11	0.11
12	0.10
13	0.11
14	0.03
15	trace

(*iii*) Swathe width — samples were collected in a swathe of 130 yards, but the bulk of the spray was deposited over a narrow swathe as illustrated in *Figure 12*.

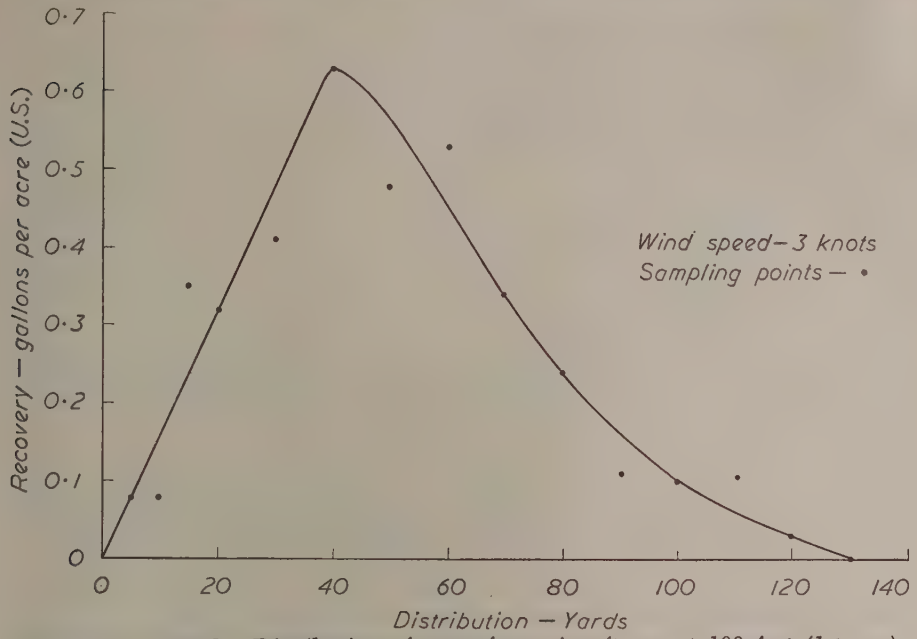


Figure 12 Trial 3. Distribution of spray from aircraft run at 100 feet (1st run).

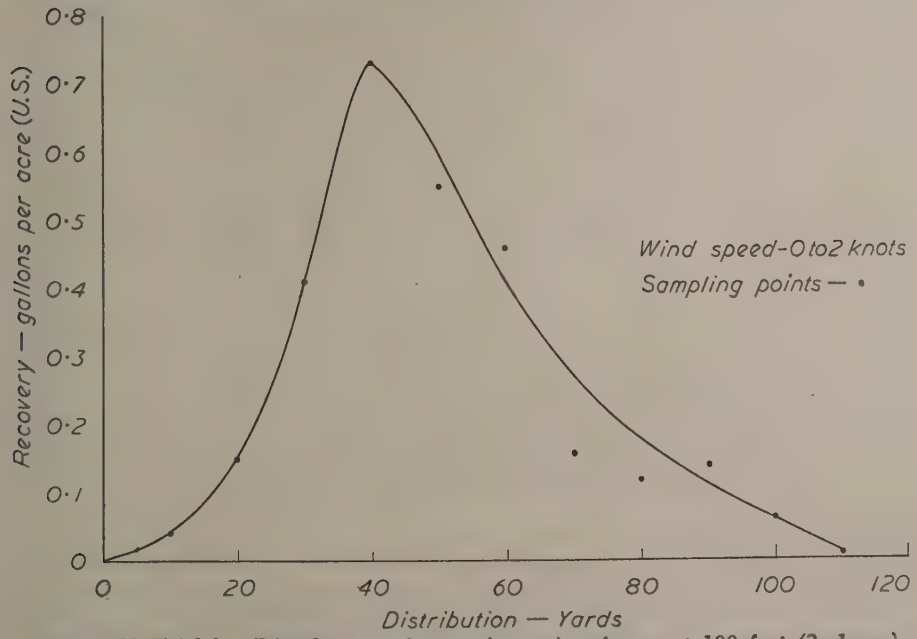


Figure 13 Trial 3. Distribution of spray from aircraft run at 100 feet (2nd run).

Table 8 A. Second Run
Drop Spectrum Expressed as the Percentage of Material Recovered

Aircraft height — 100 feet.

Drop diameter μ	Percentage recovery	Cumulative percentage
Up to 100	0.82	—
101 — 200	22.06	22.88
201 — 300	58.77	81.65
301 — 400	18.35	100.00
401 — 500	trace	—

(*i*) Drop size — the mass median diameter calculated from the drop spectrum in Table 8 is 240 μ and again the narrow range of drop sizes is evident. Just over 58% of the recovery was in the form of drops in the range 201 — 300 μ diameter.

(*ii*) Ground recovery — 55% of the sprayed solution was accounted for within the sampled area and the spray distribution was of the same pattern as in the first run.

Table 8 B. Second Run
Distribution of Spray Downwind from Aircraft Track Expressed in U.S. Gallons per acre for each Sampling Point

Aircraft height — 100 feet.

Sampling point	Estimated recovery gallons/acre
1	0.02
2	0.04
3	0.15
4	0.41
5	0.73
6	0.55
7	0.46
8	0.16
9	0.12
10	0.14
11	0.06
12	0.01

(*iii*) Swathe width — the spray width was 110 yards with the majority of the volume falling in a narrow swathe (*Figure 13*).

Although it was stated earlier that the object of these assessments was not to embark on a full examination of spray characteristics, due to the necessity of releasing the aircraft for other duties between experiments, it was felt that these assessments would result in savings in flying time in the field applications. Briefly, the following points have emerged from these calibration and assessment trials.

In the trials recorded in Tables 3 and 4 the satisfactory nature of the drop spectrum and knowledge of ground contamination enabled field trials to be carried out with the boom and nozzle equipment although the output of one gallon per acre when swathes were one chain apart was below what had been considered necessary to secure adequate coverage. The trial run at 250 feet was made as a check on the lower run, the drops being easier to assess as drop size groups were more distributed over the sampling papers.

With the boom and Simplex pump, details of the assessment runs which are given in Tables 5 and 6, no attempt was made to follow up the results because trouble was experienced with the pump mounting and our experimental work called for equipment having a higher maximum output. The maximum output obtained with the Simplex pump and No. 10 nozzles was 28 gallons per minute at an airspeed of 90 m.p.h. This is equivalent to a dosage of 2.3 gallons per acre with a swathe width of one chain. In Experiment 5, referred to later, however, the rate of application was calculated at 3.0 gallons per acre and it is possible that such a variation can occur through different valve settings which may be slightly altered each time the gear is mounted in the aircraft.

Perhaps the most striking fact emerging from the assessment of the I.C.D. equipment, Tables 7 and 8, is the narrow drop spectrum range. In the first run 55% of the recovered spray was in the drop range 201 — 300 μ and in the second run the figure was 58%. The mass median diameter although smaller than that produced by the nozzles, did not in field tests adversely affect the result. As the height of application in the field was just above the tree tops, the problem of drift was not important.

Defoliation Trials

Field applications to study defoliation in these trials were confined to the period May to October, following refoliation of trees after wintering and before the onset of the main wet season. It should, however, be appreciated that this period was chosen for ease in assessing results free from complicating seasonal and weather factors. It is not suggested that the success of a defoliant application would be affected by the time of year when it was made. Furthermore, trials had to be carried out on old rubber due to be cut out for replanting, and this limited the period for observations.

Experimental spraying commenced in May 1952. In all the aerial spray experiments the concentrations given are percentages (v/v) of n-butyl 2,4,5-T (80% acid equivalent) in Shell Diesoline. Spraying was carried out from a height of approximately 30 feet above the trees with an aircraft speed of approximately 90 m.p.h. and swathes spaced one chain apart.

In Experiments 1 to 4 described below, carried out in 1952 and 1953, the defoliant was applied with the boom and nozzle equipment and immersion pump. The boom was fitted with 19 No. 3 nozzles which gave an output of one gallon per acre flying at 90 m.p.h. with swathes one chain apart. By the end of 1953 the wind driven Simplex pump of larger output capacity had been obtained and so also had the I.C.D. rotary brush conversion. With the delivery of these two units we were in a position to apply more than one gallon per acre without altering the flying speed or swathe width. No spraying was undertaken in 1954 through lack of funds, but in 1955 these equipments were employed in Experiments 5 and 6.

Experiment 1. An area of 195 acres of old rubber scheduled for replanting on Carey Island was chosen as the site. It was ideally situated for the preliminary tests in that it was within a few minutes flying time from our base at Port Swettenham; further, all approaches to the area were level and on one side there was jungle where spray drift clearly did not matter.

The first applications were made on 1 and 2 July 1952. Four concentrations were applied, namely, 0.5%, 2%, 10% and 20% of n-butyl 2,4,5-T with the addition to each of 0.01% pentachlorphenol. Spraying was carried out immediately after daybreak, the aircraft applying each concentration at a rate of one gallon per acre to a block of ten acres. The principal object was to determine the concentration of 2,4,5-T required for effective defoliation of mature trees when applied in solution at this low rate. A subsidiary object was to investigate such matters as ground to air control and methods of indicating spray runs.

Defoliation was first observed about 6 days after spraying, and 12 days later the majority of the trees in the 2%, 10% and 20% treated areas were leafless. Little leaf fall occurred in the 0.5% block. Inspection carried out both from the ground and the air 18 days after treatment led to the conclusion that, judged by defoliation alone, there was nothing to choose between the results obtained with the three higher concentrations. From this it could be inferred that a concentration of 2% was in the region of the optimum.

The best criterion by which to judge the results would have been the rate of refoliation, but as to use this would have entailed a delay of unknown duration which could not be accepted as the aircraft was required for other duties, it was decided to proceed with the second experiment on the basis of the first assessment.

Experiment 2. The second experiment was carried out on Carey Island on 23 and 24 July 1952, again using the boom and nozzle gear. On this occasion 2,4,5-T was used at two concentrations, namely 2% and 5%, with 0.01% pentachlorphenol. Each concentration was applied to an area of 50 acres. In treating the 100 acres, 108 gallons of solution were used.

Discolouration of the leaves was general 4 to 5 days after application had been made. Five days later a fair amount of leaf fall had occurred in the 2% block, but in the area which had been sprayed with the 5% solution the majority of the leaves, although dead and brown, were still clinging to the branches. Nevertheless the impression gained was that the 5% solution had done the more thorough job. This view was strengthened by later observations.

Defoliation was virtually complete in both blocks about a fortnight after treatment (*Figure 14*), though here and there a few branches could be found which appeared to have escaped the spray. Most of these were lower branches that had been protected by a particularly dense canopy. Some branches which escaped were borne on trees bordering gaps in the stand caused by root disease. They appeared to have owed their escape to up-currents of warm air rising from the open ground, or to eddies set up by aircraft as it passed over these gaps in the canopy.

Precise observations on the rate of refoliation proved difficult to make because of the amount of variation that occurred not only between individual branches but also between trees in the same treatment. It could be said, however, that some trees could be found which were starting to refoliate four weeks after treatment at all concentrations. The proportion of these appeared to be highest in the area sprayed with the 2% solution, but many trees in both the sprayed blocks were entirely leafless five weeks after treatment.

In general, most of the new shoots arose from dormant buds situated some way below the tips of the branches, indicating that dieback had taken place.

Figure 14. Carey Island. General view of experiment area two weeks after treatment. A - 50 acres treated with 5% 2,4,5-T; B - 50 acres treated with 2% 2,4,5-T. The early applications given in Experiment 1 are in C.

Observations on this experiment had to cease when the area was poisoned with sodium arsenite in preparation for replanting, some three months after treatment, by which time most of the trees had refoliated to some degree; but the poverty of the canopy and numerous bare branches made the treated blocks conspicuous from the air over a distance of several miles. The block treated with 5% 2,4,5-T was most marked in this respect.

Experiment 3. As the result of the 1952 experiments it was felt that an investigation of the effect of higher gallonages, and repeat applications, was required. The equipment at our disposal, however, could not give higher rates of applications without duplication of spray runs or reduction in swathe width. Neither device was considered advisable as they would at the same time alter factors other than rate of deposit. This aspect of the investigation therefore had to await the arrival of the Simplex pump with its greater output.

The third experiment, started on Carey Island in May 1953, was designed as an investigation of the effect of concentration combined with repeated applications. Three concentrations of 2,4,5-T were chosen — 5%, 7%, 10% — and applications were made once, twice or three times and with intervals of one month or two months between them. Pentachlorphenol at 0.01% was included in the solutions. The boom and nozzle equipment was used, the aircraft flying over a swathe of one chain at 90 m.p.h. and 30 feet above the trees. The following programme was followed, (*a*) application in May; (*b*) application in May and June; (*c*) application in May, June and July; (*d*) application in May and July. Details of the treatments are given in Table 9.

Table 9. Experiment 3.
Rate of Application, Interval Between, and Total Quantity per Acre

Concentration	Treatment	Month of application			Total quantity applied
		May	June	July	
		Average rate — gal/acre			gal/acre
5%	1	0.98	—	—	0.98
	2	0.98	1.12	—	2.10
	3	0.98	1.12	1.05	3.15
	4	0.98	—	1.05	2.03
7%	5	0.96	—	—	0.96
	6	0.96	0.96	—	1.92
	7	0.96	0.96	1.08	3.00
	8	0.96	—	1.08	2.04
10%	9	0.91	—	—	0.91
	10	0.91	1.00	—	1.91
	11	0.91	1.00	1.22	3.13
	12	0.91	—	1.22	2.13

As on previous occasions, observations had to cease when the trees were poisoned in preparation for replanting, which was before the final result, as judged by refoliation, could be assessed. The period of observation was limited by this factor to 18 weeks from the first application in May; 14 weeks from the second; and only 10 weeks from the third.

Defoliation followed the usual trend, being more or less complete in 14 days after the first application. The 10% solution, however, was rather superior to 7% and 5% in this respect although this was not noticeable when the trees started to refoliate at which time the amount of new leaf present in the 10% and 7% areas was very similar. The lowest concentration was inferior.

Assessing the results of repeated applications at intervals was much more difficult. Three applications over three months, and two applications with two months between, both left the trees nearly denuded of leaf. It should be noted, however, that it was not possible to observe these two treatments over the equivalent period to that for one application only, or for two applications with one month between them. What the final result would have been can only be a matter for surmise. However, the experiment did indicate that at the rate of approximately one gallon per acre it is not possible to keep trees leafless for a period in excess of one month.

During the applications in June rain immediately followed the spraying with 5% and 7% solutions, while the 10% solution was actually applied during heavy rain. Defoliation took place normally, the rain apparently having had no effect on the result.

Experiment 4. The spraying technique had been worked out over perfectly flat land. Whether it could be applied successfully in hilly country, and what additional difficulties or modifications would have to be met, were unknown. An experiment was therefore designed to provide information on communication and ground control under these conditions, and to find out whether adequate coverage could be obtained with the aircraft flying on a level course or whether it would be necessary for it to follow the slope of the hills.

The site chosen was on Rantau Panjang Estate where an area of old rubber scheduled for replanting included three small hills, the slope being from slight to steep, and the highest point approximately 200 feet above the lowest.

The manoeuvrability of the Beaver made it possible to follow closely the slope of the land along the flight path. It was therefore decided to compare the ground recovery from a spray run at 280 feet — 30 feet above the highest tree top — with that from a run flying as nearly as possible 30 feet above the trees. Six rows of sampling papers were set out for each application, 200 yards apart, with 10 yards between papers. Variability of the samples was so wide that the results were worthless. The cause was thought to be the unevenness of canopy of the trees, and it was decided to assess the results by observations on defoliation. Two six-acre plots were then sprayed, in the manner already described, with a solution of 10% of the defoliant and 0.01% pentachlorphenol in July 1953. Three swathes each a chain apart and 20 chains long were applied to each plot, 6.6 gallons of solution being used.

Defoliation was particularly extensive and hardly a branch, in either of the application methods, retained green leaf after 12 days. Some slight refoliation started after five weeks but by the 18th week, when the stand was destroyed by poisoning, refoliation was very sparse and weak. The results were indistinguishable whether the application had been made from the level flight at 280 feet or the flight at 30 feet above the trees. It would appear from this experiment, therefore, that the risk involved in what could be termed cross contour flying does not warrant such a method of application.

Experiment 5. For the areas used in experiments so far described we had depended on estates to provide us with sites in areas due for replanting. The understandable reluctance of managers to have the trees destroyed sooner than is necessary imposed a considerable limitation on the period during which observations could be made. It had never been found possible to follow the full effect of treatment or to explore thoroughly the result of multiple applications. To overcome this difficulty a site for the fifth experiment was found on our Experiment Station at Sungei Buloh.

This experiment was designed to compare equal outputs from the boom and nozzle gear, fitted with Simplex pump, and the rotary brush gear, in conjunction with multiple applications. Unfortunately it was not possible to continue beyond the first application with the nozzle equipment as the supports for the Simplex pump fractured and to replace these was a major operation for which time could not be spared. Subsequent applications were therefore all undertaken with the I.C.D. rotary brushes. Details of the treatments are given below:

Table 10. Experiment 5.
Details of Treatment, Intervals and Equipment

Treatment	Date of application	Concentration 2,4,5-T	Gallons per acre	Equipment
A	June	10%	3.0	Bo
B	June	5%	3.0	Bo
	July	5%	3.0	Br
	June	1%	3.0	Bo
C	July*	5%	3.5	Br
	August	1%	2.5	Br
D	June	5%	3.0	Br
	August	5%	3.0	Br
	June	1%	3.5	Br
E	July	1%	1.5	Br

Bo – Boom with Simplex pump and 19 No. 10 nozzles
Br – I.C.D. rotary brush with 4 brushes in each rotor
* – 5% concentration applied in error

It is thought that the inconsistent output figures recorded above were due to errors in measurement in treating plots of only one acre, where the quantity of spray used was small. The low figure of 1.5 gallons used on treatment *E* in July was due to incorrect setting of the output control which did not allow the valve to open fully.

There was evidence that spray distribution was better with the rotary brush gear as indicated by the damage to the leaves caused by actual contamination with the spray. However, this effect may have been due to the greater area of the canopy protected through the trees being larger, as occurred particularly in treatments A and B, compared with those in other treatments.

Defoliation in all treatments was complete within 14 days, but by the time of the second application in July one month after the first, some refoliation occurred low down on the branches. By August the areas A and D, which had received only one application before, showed more leaf than those which received two applications, but again the concentration had little effect. There was, however, rather more leaf in the 10% treatment.

Examination of the area in April 1956, ten months after the first application and eight after the last, showed it to be still largely defoliated although the trees had not been killed. Considerable dieback had occurred in all treatments. Of the five treatments, *D* was the best (two applications of the 5% concentration with two months between them) and the refoliated canopy on the trees was not more than 20% of the original. In treatments *B*. *C* and *E* dieback was less extensive and refoliation slightly more, with an indication that *C* was rather better than *B* or *E*. The failure to differentiate between *B* and *E* was no doubt due to the larger trees encountered in *B*.

This experiment indicated that three gallons per acre of a 5% solution, with two months between applications, gave best results.

Experiment 6. An area of 200 acres of old abandoned rubber on Nordanal Estate in Johore was offered to us for experimental spraying. This area was entirely suitable for an extended experiment and as no immediate replanting programme was foreseen it was therefore available for observations for at least one year. The experiment was designed in three parts, (*a*) a trial of concentrations of 2,4,5-T and 0.01% pentachlorphenol at three gallons per acre with one or two applications; (*b*) a trial with 5%

Table 11. Experiment 6.
Details of Treatments of Plots Receiving One or Two Applications of Various Concentrations of 2,4,5-T at 3 Gallons per Acre

Plot	Date of application	Acreage treated	Concentration %
1	June	10	10
2	June	10	5
	August	5	5
3	June	10	10
	August	5	10
4	June	10	2
	August	5	2
5	June	10	1
	August	5	1

2,4,5-T and 0.01% pentachlorphenol at three rates of application and (c) a trial applying the defoliant followed the next day by a separate application of 1% pentachlorphenol. Applications were made with the rotary brush I.C.D. equipment.

a Details of the trial on concentrations and applications are given in Table 11.

As plots 2 to 5 were all sprayed in August over half the area which had been sprayed in June, within these plots there is a comparison between one and two applications with an interval of two months between them.

Between the treatments listed in Table 11 the assessment of differences was extremely difficult as there was little to choose in effectiveness between them all along. The conclusions were reached that the concentration of defoliant had only a small effect on the ultimate result. The 1% solution of 2,4,5-T could, however, be regarded as inferior. There was nothing to choose between 5% and 10%, which were both rather better than 2%. Refoliation in all treatments after 10 months was very sparse. Not without close examination was it apparent that the results of two applications with two months between them were better than those following a single application.

b In the trial comparing rates of application of 2,4,5-T three quantities of 5% solution of 2,4,5-T — 2.9, 2.3 and 1.7 gallons per acre — were applied to blocks of 30, 20 and 20 acres respectively. These output rates were obtained by three settings on the control namely, fully open, half open and quarter open. It is apparent, however, that the rate of output did not follow this simple relationship. Better control of output can be obtained by changing the number of brushes in the rotors.

The highest rate of application caused more uniform defoliation than the lower rates, but otherwise differences in their effect were not sufficient to be noted. It is appreciated, however, that the range of volumes applied was not great. Nine months after treatment the canopies were still very thin.

c In September, trees in what had been the guard rows between plots, amounting to 60 acres, were sprayed with 5% 2,4,5-T at the rate of 2.4 gallons per acre, followed the next day by an application 2.9 gallons per acre of 1% pentachlorphenol. Rather rough and wet conditions on the first day made accurate flying difficult and the volume applied was low. Much more rapid defoliation followed this application, however, the amount of refoliation after seven months was only slightly more than where the low concentrations (0.01%) of pentachlorphenol was applied with the 2,4,5-T. It would not appear that the effectiveness of the defoliant is materially affected by the pentachlorphenol spray and the advantage to be gained by applying in this manner a higher concentration of fungicide than could be included in the defoliant mixture, will substantially outweigh the slight reduction in effectiveness of the defoliant.

Figure 15 shows the experimental area photographed six months after treatment.

DISCUSSION

Should an outbreak of South American leaf blight occur, immediate steps to eradicate the disease would be necessary. To be effective such action must be implemented without delay and carried through as quickly as possible. Owing to the inaccessibility of most areas of rubber to heavy ground spraying equipment, the only satisfactory method of dealing with an outbreak would be by aerial spraying to defoliate diseased trees and a certain belt surrounding them. The whole purpose of the investigation herein reported was to establish whether a method of aerial application could be used and, if so, to find a suitable defoliant and procedure.

In the earlier tests with defoliants, water soluble materials were examined but the necessity of overcoming evaporation in an aerial spray led to further work with these

Figure 15. Nordanal Estate. General view of defoliated experimental area.

being dropped. Attention was then directed to oil soluble herbicides, the immediate choice being the chlorophenoxyacetic acids. The n-butyl esters were chosen because of their solubility in oil, and, of these materials, 2,4,5-T was outstandingly the best. Hevea rubber is particularly sensitive to it. Field trials have shown that the concentration is not critical, but good results follow the application of 5% of the n-butyl ester of 2,4,5-T (80% acid equivalent). Higher concentrations do not give better results but rather the reverse (judged by refoliation), by speeding defoliation of the leaves before the hormone has been fully translocated. Comparison of rates of application shows little difference in defoliation, but on the rate and amount of refoliation the effect is marked. It has not been possible to compare closely various rates per acre between the boom and nozzle gear and the rotary brushes. With the I.C.D. rotary brush, an application of three gallons per acre is more effective than at lower rates, and equally effective results were found with the smaller drop sizes produced by the I.C.D. equipment.

Pentachlorphenol, when included in the defoliant solution in quantities likely to prove lethal to the disease, resulted in premature leaf fall and subsequent earlier refoliation, but it has been established that a separate application of the fungicide can be made on the day following the defoliant treatment without markedly affecting the result. Such a method of split application would be recommended.

Assessment of the two application equipments has shown the I.C.D. rotary brush to be suitable although the drop size is smaller than that produced by the boom and nozzles. There is however, little to choose between the two systems and if the mounting difficulty of the Simplex pump had been overcome, this equipment would have been quite suitable too. The flexibility of control that is available with the variable number of brushes in the I.C.D. gear is, however, an added advantage.

For the successful operation of a spraying programme, communication between the aircraft and ground control, and between ground parties is essential. The apparatus used in our trials has proved suitable but smaller and more portable sets for the ground parties have since become available. Balloons were used to mark spray runs to guide the pilot of the aircraft, but some more convenient method is required. It may be possible to dispense with markers for indicating individual spray runs, and trials confirmed that after the pilot had experience he was able to judge swathe widths accurately.

As the result of the field applications the possibility of the use of aircraft for defoliation of rubber trees has been established. The recommended concentration of 2,4,5-T has been assessed at 5% when applied at a rate of 3 gallons per acre, but repeat application at intervals not exceeding six weeks are required to prevent refoliation.

SUMMARY

The report covers an investigation of a method of defoliation of rubber trees by the application of a herbicide from the air. This is considered the only practicable method of attempting to eradicate the disease South American leaf blight, should an outbreak occur.

Screening tests of a large number of materials established the superiority of the n-butyl ester of 2,4,5-T as a defoliant for this purpose. In field tests to mature trees it has been shown that 5% of this formulation in three gallons of gas oil per acre constitutes the most effective defoliant of the materials examined, a single application of such a mixture keeping treated trees free of leaves for four to six weeks.

The desirability of incorporating a fungicide (pentachlorphenol) into the 2,4,5-T solution has been examined and it is shown that there is a limit to the amount that can be added without reducing the ultimate effect of the defoliant.

A de Havilland Beaver aircraft was chosen for the application of the defoliant and an assessment was made of the characteristic of the spray produced from two types of spraying gear fitted to this aircraft — boom and nozzle, and rotary brush.

Methods of marking and controlling the spraying operation have been examined.

In an investigation of this nature the help received from various organisations and persons is invaluable and of the assistance received from many, particular mention must be made of the Colonial Insecticide, Fungicide and Herbicide Committee; the Ministry of Supply, Chemical Defence Experimental Establishment at Porton and of Professor Blackman at Oxford. In Malaya, the cooperation is gratefully acknowledged of the Director of Civil Aviation, the Department of Telecommunications, the Federation Air Service and Malayan Airways. In addition I would record my appreciation for the cooperation afforded during our spraying trials by the Resident General Manager of Carey Island and the Managers of Rantau Panjang and Nordanal Estates.

The success of the aerial spraying experiments was in no small way due to Mr F. J. Anderson, Chief Engineer of the Federation Air Service who was responsible for maintaining the aircraft and fitting the spraying equipments and also to Captains P. R. Gaskell, W. Greathead, and A. E. Nichol who so patiently flew the aircraft to our exacting requirements.

Last but not least must be mentioned Mr R. A. Altson, late Head of the Pathological Division, and his successor Dr A. Newsam, whose encouragement and help made the

project possible and to those other members of the Pathological Division upon whom much of the routine work fell.

Pathological Division
Rubber Research Institute of Malaya
Kuala Lumpur

September

REFERENCES

Altson, R. A. (1950) Pathological Division. Report for the period January 1946 to December 1948. *Rep. Rubb. Res. Inst. Malaya,* 1945 - 48, p 170.

Hilton, R. N. (1955a) South American leaf blight *J. Rubb. Res. Inst. Malaya, 14,* 326.

Hilton, R. N. (1955b) South American leaf blight *J. Rubb. Res. Inst. Malaya, 14,* 328.

Hutchison, F. W. (1955) Aerial application of a defoliant to hevea rubber trees. *Pestic. abs. nws. summ. 1,* 9.

Lane, W. R. (1947) A microburette for producing small drops of known size. *J. sci. Instrum. 24,* 98.

Pink Disease of Hevea Caused by Corticium salmonicolor Berk. et Br.

R. N. HILTON

An account is given of the present state of knowledge concerning pink disease, with special emphasis on post-war field observations in Indochina and Malaya.

PINK DISEASE HAD BEEN STUDIED on other plants of economic importance before its appearance on hevea. It was first reported on coffee by Thwaites from Ceylon in the year 1870. A. W. P. Zimmermann, working with the disease on coffee in Java from 1896-1901 recorded that hevea too could be attacked, and in 1906 C. J. Bernard published an account of the disease on hevea. A. Rant worked on the disease on cinchona in Java and was able to cross-inoculate from cinchona to hevea, and vice versa. He recognised the various forms and described them fully. L. Zehntner carried out similar studies on the disease on cacao in Java. At this time hevea was being planted on a large scale in Ceylon, and, although no special studies of pink disease were made, control was being practised there with Bordeaux mixture. H. N. Ridley recorded the disease in Malaya about 1906. A year or two later it was realised that pink disease was serious and F. T. Brooks was appointed to work specially on the disease after C. K. Bancroft had left Malaya for British Guiana in 1913. A. Sharples worked with Brooks, and their joint paper was published prior to cessation of interest in the disease with the restrictions on planting that came into force from 1920 onwards.

About 1937 the research centre at Laikhê in Indochina was started, with F. Bugnicourt as Phytopathologist. The disease proved particularly serious in Indochina. M. Borget in 1947 took advantage of the absence of treatment during the war years in 450 acres of experimental plantings made at Laikhê from 1940 to 1942, to analyse the subsequent incidence of disease statistically. He continued experimental work until 1951, and was followed by P. Tixier.

The extensive programme of replanting carried out in Malaya since the war has created large areas of young rubber comparable with those of the boom years of 1904-1908. As a result, interest in the disease has been revived. This time, however, the majority of the young trees are of selected origin and their relative clonal susceptibility becomes a significant factor.

This paper presents the results of further experimental work and field observations, and incorporates a summary of work published since the paper of Brooks and Sharples.

THE DISEASE

Geographical Distribution

Asia—Pink disease was first recorded on coffee in Ceylon, then on coffee in Malaya, (RIDLEY 1897) and on coffee in Java (ZIMMERMANN 1899). The first record on hevea was from Java (ZIMMERMANN 1901), and subsequent records from Borneo (RIDLEY 1904), Malaya (RIDLEY 1905), Ceylon (PETCH 1908), South India (PETCH 1909), Indo-china (VINCENS 1920), Philippines (LEE & YATES 1920), and Burma (RHIND 1926).

America—The first record of pink disease from the American continent was from Dominica and St Lucia as *C.lilacino-fuscum* Berk. et Burt on cacao (NOWELL 1916).

COMMUNICATION 323

Specific records on hevea are for Brazil (Mendes 1947), Mexico (Martin 1947), and Peru (Langford 1953).

Africa—Pink disease is widespread in French Equatorial Africa, the Cameroons, the Ivory Coast, and the Belgian Congo (Saccas 1953).

Distribution within Malaya

Some indication of the distribution of pink disease throughout Malaya has been given for the years 1915 to 1925 by the reports of the inspection service of the Department of Agriculture. As it is a windborne disease with a large number of alternative hosts, it can be regarded as potentially present throughout the whole country. Absence of a record of the disease cannot be taken to mean that it has not extended into an area. It could indicate absence of material of susceptible age and clone, or local conditions not favouring disease development. The object of a study of distribution of disease is to discover these local conditions. Studies made before the war do not achieve this, as they depended on visits within arbitrary administrative units, in many of which there may have been little hevea growing and none of susceptible age.

A survey based on administrative units is useful only if a disease is spreading into an area and barriers have to be organised. It is interesting to recall that from 1914 to 1954 half mile barrier belts have been left along district boundaries in certain places for quarantine purposes. Administrative units may be used if they are small enough for conditions over the area to favour or not to favour the disease; records may then be made under these names for survey purposes. The smallest administrative unit in the Federation of Malaya is the mukim, of which there are 828, comprising 70 State districts. Surveys made before the war were on a mukim basis (South 1921). One obvious survey unit to choose is the estate, as this is guaranteed to have hevea, even if not of susceptible age; it often has a resident manager from whom information can be obtained, and it is of convenient size and number, there being 883 estates of over 500 acres. An estate survey was made in 1956 by sending reply-paid postcards and following up doubtful cases by personal visits. The resulting information was consolidated with other records by flagging a 6 miles:1 inch map marked with the distribution of: (*i*) areas planted with hevea, (*ii*) coast deposits and alluvium, (*iii*) lowland forest, (*iv*) rainfall (*v*) land over 750 ft. A simplified copy of this map omitting lowland forest appears as *Figure 1*. A broad summary of information that the map has revealed is given below:

In Johore, the Mukim of Kluang in the Kluang district is severely affected, whereas the coastal mukims of Muar district are entirely free. In Malacca, the disease nowhere appears to be severe. It is general in the Seremban and Kuala Pilah districts of Negri Sembilan, but rare in the Port Dickson district. Selangor is notable for the severity of pink disease in the inland districts of Ulu Selangor, Kuala Lumpur, and Ulu Langat, and for its absence in the extensive hevea growing area of the coastal districts: Kuala Selangor, Klang, and Kuala Langat. Perak is severely affected in its inland districts of Batang Padang, Kinta (particularly the mukim of Ulu Kinta), Kuala Kangsar, Larut, and Selama. The coastal districts of Krian, Matang, Dindings, and Lower Perak have much less. In Kedah, the districts of Bandar Bahru, Kulim, and Kuala Muda are affected while Sik, Kota Star, and Kubang Pasu are not. In Kelantan, estates near Kuala Krai are severely affected. In Trengganu, it is present in the only estate area — in the Mukim of Kerteh, Kemaman district. The disease is known to be severe in the few inland areas of Pahang where there are estates — the Kuala Lipis and Tanjong Besar mukims of Lipis district; near Triang and Mentakab in the Temerloh district, and at Sabai mukim in the Bentong district — but it has not appeared on estates near Kuantan, and has been reported only once near Pekan.

Economic Importance

Pink disease was considered to be of sufficient economic importance to be gazetted as a notifiable disease under the Agricultural Pests Enactment 1913 (Brooks 1914). Treatment was made compulsory and supervised by Assistant Agricultural Inspectors (South 1915). The importance attached to the disease at that time by the Department of Agriculture of the Federated Malay States is shown by 355 court cases with over $4000 taken in fines. It was realised that the reluctance of smallholders to spend money on treatment was due to their recognition that the disease rarely caused severe damage, and was usually of negligible importance (South 1917). From 1916 to 1920 there was an apparent reduction in the amount of the disease, and by 1925 it no longer caused grave concern (South 1926), the Malayan Agricultural Journal for that year not even mentioning it. In the annual *Report* of the Rubber Research Institute for 1929 it is mentioned as being of much less importance than in 1927 and 1928.

It is clear from reading the agricultural inspectors' records, that the occurrence of the disease was erratic and that it was not progressively spreading. Differences between one area and another may well have depended on the efficiency of inspection and the extent of hevea plantings of susceptible age under conditions that favoured the disease.

Differences in the attention paid to the disease depend on the amount of 3 to 6 year old rubber in the country (South 1926), but there is little doubt that the disease has not proved to be as serious as was at first feared. Indeed, much of its importance before the war can be attributed to the expensive control measures employed. With the development of inexpensive control measures (page 290) and the realisation that the disease is only locally serious, it can be assessed to be of minor economic importance over the country as a whole. On an individual Malayan estate it may be of some importance, as treatment may be necessary to prevent loss of whole canopies, or even trees.

Symptoms

The pink coloured crust that gives the disease its name represents the fully mature stage. An infection may take several months to advance so far and many hundred square centimetres of bark may be killed before symptoms are obvious from the ground. The symptoms are to be sought on any stem or branch that has formed brown bark, but not extensive layers of cork. They may appear on twigs only 1 cm in diameter and on trees aged from 18 months to many years. It is most common and most damaging on trees from 3 to 7 years old. The first indications of attack are exuding drops of latex. Later the fungus appears, as white silky threads on the bark surface. Usually the threads are seen as only a faint sheen visible, in a favourable light, from several feet away. Under conditions of vigorous growth the threads envelop the branch — the 'cobweb' stage — and are then readily seen. Under ideal conditions they appear a diffused pink. The threads dry up when the outer bark dies. At this stage, pink masses of sterile mycelium begin to appear. There are two forms: 'pustules' and 'crust'. The pustules, about 0.25 mm across and pale salmon pink in colour, erupt in lines through cracks in the bark. The whole circumference of a branch for 50 - 60 cm may be covered with them. They do not grow together into a crust, but disappear as the dead bark sloughs off. Pustules may appear at an early stage of infection and consist of small masses of undifferentiated tissue. Although the pustular form has the aspect of a fragmented form of the crust, in general it appears earlier than the crust. Pustules sometimes appear immediately after the bleeding which signifies the first death of the bark. The crust is of identical colour with the pustules but, unlike them, develops most strongly on the lower side of the branch (*Figure 8*). Even a slight lean in an otherwise vertical affected stem will cause heavier

growth on the side facing the ground. The surface of the crust breaks into irregular cracks. The bark death and penetration of the wood that accompany the sterile forms are followed by secondary symptoms. Tears of latex run down the stem, congealing in long black streaks. Below the injured portion dormant buds develop into numerous side shoots, and the dead terminal branches surrounded by green shoots make the disease conspicuous from a distance.

It is from the sterile stages that the disease is recognised and the two fertile stages are of negligible diagnostic significance although, of course, they are of the greatest importance in the life history of the disease. The 'corticium' stage that produces basidiospores consists of a smooth, pinkish white, clammy surface covering the pink crust. The other, the 'necator', consists of orange-red pustules, composed of tight masses of spores, scattered over the bark surface — in contrast with the pink sterile pustules that occur in lines. The characteristic position for the necator pustules is on the upper surface of side branches that carry the pink crust on their lower surface.

The overall symptom that draws attention to the disease is death of the branch, showing as groups of dead leaves that fall, exposing bare shoots. Infection frequently spreads down to the fork below it and then up the other shoots so that a whole branch is affected. When this happens at the main fork of a young tree the entire canopy may be destroyed (*Figure* 2).

The main fork of a tree may be infected without any obvious infection on the branches. Persistent infections of this type are common in trees 7 to 9 years old, which are just past the stage when pink disease is generally a matter of concern. The bases of the main branch may be enveloped by the pink crust with extensive bleeding and loss of canopy if left untreated. In contrast with this infection of the shaded fork of a tree past the most susceptible age, is the infection of the stems of plants 1 to 2 years old, which have often not even started to branch and are exposed to full sunlight. The infection occurs on brown bark and passes through the usual stages. It is an unusual occurrence, but when conditions have favoured such a form of attack in one tree, two or three neighbouring trees are often attacked also.

There is one organism — *Trichothecium roseum* — which simulates the disease to a remarkable degree when it grows on old wounds. It is exactly the same colour as the pink crust, and has been found several times growing on top of old pink disease lesions. Spores of this fungus were tested for pathogenicity of branches of three-year-old RRIM 501 at various stages of bark development, with and without Alkathene cover. No infection occurred.

Assessment of the disease—Defining a 'case' of pink disease as one affected branch, there may be several on one tree. A case may be mild, moderate, or severe, according to the size of branch down to which the mycelium extends. A planting of nine-year-old trees may have many more cases per acre than there are trees per acre, but the attack can still be termed mild, as only small terminal branches will be involved. On the other hand the number of cases in a planting two to three years old may be only half the number of trees, yet the attack as a whole might be considered severe.

CAUSAL ORGANISM

Description

As the pink disease fungus has several forms and attacks a number of crops of economic importance in different parts of the tropics, it is not surprising that it has synonyms. The name that has priority is *Corticium salmonicolor*, given by Berkeley and Broome to the original collection of the corticium stage from coffee in Ceylon (Berkeley & Broome 1873). The second occasion on which the fungus was described was also on coffee, but the necator stage and in Malaya, given the name *Necator*

discretus (Massee 1898) and subsequently quoted as *N. decretus*. The third occasion was the corticium stage again on coffee from Java, and named a new species, *Corticium javanicum* (Zimmermann 1901), in ignorance of the original record from coffee in Ceylon (Petch 1912). When the corticium stage was found in Malaya (Ridley 1905) it was mistakenly named *Corticium calceum* Fries (Ridley 1906) which delayed recognition that the destructive pink fungus in Ceylon, Malaya, and Java was the same species. The true situation was realised when outbreaks on hevea in Ceylon were recognised by workers there as the same as those in Java and Malaya put down to *Corticium javanicum* (Petch 1909). Then the fact that *Necator decretus* was a stage of *C.javanicum* was determined in Java (Rant 1912), and it remained only to show that the name *C.javanicum* should give way to the priority name *C.salmonicolor* for the confusion to be finally settled (Petch 1911). When pink disease was first described in Indochina, it was under the name *Corticium salmonicolor* Berk. et Br. (Vincens 1920). Recently the name *Pellicularia salmonicolor* (Berk. et Br.) Dast. has been proposed (Dastur 1946).

Culture—Corticium salmonicolor can be grown readily in culture on a variety of media. In early studies on the disease a purely synthetic medium was used composed of 0.2% each of glucose, peptone, and potassium dihydrogen phosphate (Rant 1912). Other workers have used rice, bread, corn meal, carrot, semi synthetic hevea bark medium, and the synthetic Czapek-Dox medium. Corn meal agar has been used in the present work for making isolations and maintaining cultures, and carrot or potato media have been found to give poor growth. The fungus grows vigorously on sterilised fragments of hevea bark or wood. Growth is nearly always of the same type as the cobweb form. At times red mycelial aggregates may form, particularly in the region of the cotton wool plug in a Roux tube (Brooks & Sharples 1915). Brooks and Sharples regarded the red aggregates in their cultures as analagous with the necator stage. Observations made by the author agree with those made at Laikhê (Borget 1948b) in finding the red aggregates to be structureless, in contrast with the distinct, though irregular, spores of the necator acervulus, and therefore comparable with the pustular stage. In culture the pink colour develops more strongly in the light than in the dark.

PATHOGENICITY

The fungus *C.salmonicolor* can easily be isolated from cases of pink disease to give cultures which can be used to reproduce the disease on a healthy stem, demonstrating its pathogenicity.

Sporulation

The corticium stage develops from the crust and consists of a smooth surface with basidia producing basidiospores (*Figure 3*) 5.8 x 4.7 μ. As Brooks pointed out, the basidia are not closely packed and the fructification is more that of a *Hypochnus*. The hymenium forms over the surface of the sterile pink crust and is smooth, clammy to the touch, and glistening pink-white. It is not commonly seen during daylight hours.

The visible portion of the necator stage consists of masses of necator spores (*Figure 4*) approximately 12 μ in diameter.

No worker has succeeded in inducing spore formation in culture. To obtain basidiospores *in vitro* Borget tried growing together in one dish isolates of different origin, growing cultures on media fortified with vitamins, and culturing on fresh bark. In no case were basidiospores produced (Borget 1949). Similar difficulty has been experienced by the author. Furthermore portions of the bark already producing basidiospores in abundance ceased to do so when placed in sterile petri dishes, even though kept at 100% humidity.

Inoculation

It has always been assumed that pink disease is disseminated by wind-borne spores. Its Malay name 'chendawan angin' ('wind fungus') relates to its seemingly fortuitous occurrence. Instructions for treating the disease (Pathological Division 1951) have stressed the need to apply the fungicide to the pink incrustation before pruning in order not to disseminate spores. It is now found that the normal pink incrustation is always sterile, being a substratum upon which the hymenium forms under favourable conditions. On the few occasions when the hymenium has been observed during daylight hours it has always been under conditions of high humidity, during early morning drizzle or on a tree heavily shaded by a dense canopy.

The Hirst automatic volumetric spore trap (*Figure 5*) has proved a useful tool for investigating basidiospore dissemination. The *Corticium* spore is not sufficiently distinctive to be recognisable as a constituent of a general sample of spores from the air. The trap has therefore been used in a situation where it can be placed very close to a spore-liberating surface. The *Corticium* spores trapped are then so much more numerous than those of other species that there can be no doubt as to their identity. The bands of spores (*Figure 6*) are so heavy that on removing the slide from the trap parts of the trace may have the salmon-pink colour typical of the disease.

Statistical tests have demonstrated that inoculation from one tree to its neighbour occurs, but is of less importance than might be supposed (page 288).

Inoculation methods — Essential information when considering the success or failure of an inoculation concerns the clone, the position of the inoculum in the canopy, the diameter of the branch inoculated, the maturity of its bark, any pretreatment of the bark, the nature of the inoculum, the period during which a seal was maintained over the inoculum, and the time over which observations were continued.

In early work at the Malayan Department of Agriculture (Brooks & Sharples 1914), infection was secured by using mycelium from the cotton wool at the bottom of Roux tubes, held in place by elastic bands. Of 64 inoculations carried out under various conditions (full details of which they do not record) 7 produced the white cobweb mycelium and were counted as successful. At Laikhê (Borget 1948b) branches were successfully infected from both mycelium and mycelial aggregates, but aggregates were found best. The successful infections were made during the rainy season on trees six years of age. Inoculations made during the rainy season but on trees 25 years old failed, as did those made during the dry season on trees six years old. Inoculations were counted as successful when the cobweb stage was reached, accompanied by death of the underlying bark. In no case did artificial infections develop as far as to form a pink crust.

In work carried out at the R.R.I. Experiment Station in 1955 and 1956 various methods of inoculation have been tried. The best type of inoculum has proved to be a sliver of hevea wood that has been kept in a petri dish culture of *C.salmonicolor* after having been sterilised. It is ready for use when it supports a rich growth of mycelium. The polyvinyl plastic film Alkathene has been used for sealing. Eventually it was found that a high percentage of successes could be obtained on a branch about 2 cm in diameter with brown bark, without pretreatment, leaving the plastic seal in position for three to four weeks. For comparing the progress of inoculations at different times of the year, or with different clones, where many inoculations are needed, a rapidly applied inoculum has been devised. It consists of a piece of Alkathene 15 cm square with three scotch tape straps (*Figure 7*). The sliver of wood is placed in the centre of the square, to which it adheres by means of the agar that clings to it, and the whole is applied to the branch just like a ready-prepared first-aid dressing.

The position at which the inoculum is applied is a matter of importance; whether high or low down in the tree or towards the inside or outside of the canopy. The practical problem of gaining access to the required position in the canopy, up to a height of 30 feet, was solved by constructing an aluminium mast 18 inches square in cross-section, of 'Dexion' slotted angle (*Figure 9*).

Spores have been used instead of wood in all the above inoculation methods, but have failed to give rise to infection.

Incubation

Studies of the early stages of infection — before and after penetration of the bark — are hampered by lack of a successful method of spore inoculation. Consequently an important gap remains in our knowledge of the life history of *Corticium*. No systematic observations have been undertaken on spore germination *in vitro*, as both basidiospores and necator spores germinate very readily in distilled water at room temperature. The rapid growth has been recorded by photomicrographs (*Figures 10, 11*). Both types of spore germinate readily on a variety of culture media, giving rise to the sterile pink mycelium. The comparatively small number of natural infections that result from the numerous spores liberated means that many of them reaching susceptible hevea branches must fail to penetrate.

Infection

An infection which fails to kill the branch may die out altogether, or remain quiescent. Death of the mycelium occurs when the infection fails because of shading out of the host branch. Quiescence is more usual when dry periods intervene. In Malaya the mycelium frequently shows no sign of activity for a few months, until rainy weather starts again. In Indochina (BORGET 1949) it was found that old infections might break out one year or even two years after they first started. When dry weather follows treatment the impression may be gained that it has been successful, but later, under conditions favourable to the fungus, there may be renewed activity of the mycelium.

Host reaction—The symptoms of pink disease, and the damage it does to the tree, are the result of the reaction of the host to fungal hyphae penetrating the tissues of the bark and wood. Reaction may be to physical obstruction by the hyphae, undue absorption of nutrient, to production of toxins (BORGET 1949), or to induced tyloses in the vessels obstructing ascent of water (BROOKS & SHARPLES 1914).

The distribution of hyphae within a diseased branch has been studied by staining with Delafield's haematoxylin. For routine examination double staining with safranin picric aniline blue has been preferred. Hyphae are readily visible in the vessels (*Figure 12*) and in an established case of the disease extend in as far as the pith and along as far as the limits of the external growth.

The activity of dormant buds below the point of infection is more than the usual shooting that follows death of an extremity, and it appears that a growth-promoting substance may be produced. It may extend for several feet down the branch from the most proximal point of infection. A budding programme on an estate in the Mukim of Sungkai, in the Batang Padang district of Perak, failed completely owing to bud activity stimulated by an attack of pink disease in the budwood nursery; but subsequently using budwood from a healthy nursery resulted in a high percentage of budding successes (THOMPSON 1924).

Rate of growth on the plant—It takes several months for the disease to kill a branch large enough to be obvious from the ground, and longer still if dry weather intervenes.

When damage to the stem is sufficiently severe to cause the leaves to shrivel and die the infection immediately becomes obvious, giving an impression of sudden appearance of the disease to anyone accustomed to inspecting the plantation regularly. The progress of growth from the time of penetration to death of the branch has been followed by weekly observations on artificial infections. On one branch (*Figure 13*)

Table 1. Smallholders' Seed Garden September 1956 Census

Clone	6 years old						5 years old				4 years old	
	total	pink	total	pink	total	pink	total	pink	total	pink	total	pink
RRIM 501	873	234	—	—	—	—	599	69	866	151	362	30
Tjir 1	905	142	894	70	654	77	514	15	1160	127)	375	14
RRIM 527	—	—	—	—	—	—			901	79)	404	14
PR 107	967	33)	—	—	—	—	678	6)	941	15)	392	3
BR 2	830	26)	985	11)	—	—						
TK 14	886	14)	—	—	—	—						
PB 49	—	—	949	11)	588	22)			780	11)	342	5
RRIM 509	—	—	989	24)	637	28)						
AVROS 157			981	17	625	26)						
RRIM 526					672	25)						

Table 2. Field 48B & 48C September 1956 Census

Clone	6 years old		5 years old	
	total	pink	total	pink
RRIM 501	1023	248	185	98
New clones	3716	943	—	—
Tjir 1	909	71)	194	73
PB 86	—	—	231	23
Gl 1	1137	51)	245	5

Table 3. Comparison of 4 Clones from Large Scale 600 Series Trial F 48A

Clone	7 1st census		7½ 2nd census		8 3rd census		8½ years 4th census	
	total	pink	total	pink	total	pink	total	pink
RRIM 618	235	133	235	3	205	9	205	3
RRIM 501	366	56	366	10	339	4	339	1
RRIM 613	234	4	234	1	204	1	204	—
Tjir 1	235	18	235	—	205	2	205	1

Numbers bracketed show no significant difference.
Numbers underlined are significantly greater than those beneath.

the points of weekly advance of the white cobweb mycelium were marked by flagged pins from the time of inoculation on 1 April 1955 to death on 29 November. The rate of advance averaged just under 3 cm a week, with the underside always a few millimetres ahead. Measurements were recorded after the mycelium had descended to the

fork and was climbing the separate branches, so that any initial effects of inoculum size would have worn off.

Smaller branches succumb more quickly to infection, as would be expected. One branch, 1.2 centimetres in diameter, was killed within ten weeks of the branch from which it grew being inoculated near to the point of origin from the trunk.

Inhibition of growth of the host — At Laikhê, seven-year-old trees were measured from a plantation that had not been treated for pink disease during the first five years of its life. Comparing the girths of moderately attacked trees with those that were free, *Corticium* attack was found to lead to a reduction in girth increase, even when the damage to the canopy had not been extensive (TIXIER 1950).

Resistance and Susceptibility

Where the disease is present, and the environment favourable, the factors which determine the resistance or susceptibility of the trees in a planting are age and genetic origin. The importance of the latter has become clear only since clones have been planted on a large scale. In plantings of unselected seedlings one cannot tell whether a case is in any way due to greater susceptibility.

Effect of clone—From field experience in Malaya the most susceptible commonly planted clone has proved to be RRIM 501. No resistant clone has been recognised, although PB 86 is found to be only mildly attacked.

Definite information can be gained only by a census, analysed statistically. The post-war plantings on the R.R.I. Experiment Station have proved ideal for this purpose. The susceptibility of RRIM 501 has been consistent, with Tjir 1 in second place (Tables 1 & 2). These conclusions have been confirmed by four separate censuses at intervals of six months, which have also revealed the outstanding susceptibility of RRIM 618, alone among the RRIM '600' series clones (Table 3).

A comparison of clones was made from the results of a census of diseased trees in the experimental plantings at Laikhê (BORGET 1947, 1948 a,b). Of the fourteen clones compared statistically Tjir 1, Tjir 16, Pil B84, AVROS 214 were classified as susceptible; AVROS 188, PR 107, PB 123, Gl 1, Waring 4, and AVROS 50, as resistant; AVROS 186, AVROS 255, Dj 1, and AVROS 308 as moderately affected.

Effect of rootstock on clone—No plantings of clones on rootstocks of different seedling family have been available in Malaya for observations to be made. The census at Laikhê (BORGET 1947, 1948, a,b) indicated slight influence of seedling family stock on certain scion clones.

Effect of seedling family—No special resistance or susceptibility has shown up with the seedling families commonly planted in Malaya: Tjir 1 monoclone, P.B.I.G., and Chemara E.

In the Laikhê census only the families Tjir 1, AVROS 152, and AVROS 163, were in sufficient numbers to give a valid comparison. (BORGET 1947, 1948 a,b). The results indicated Tjir 1 seedlings to be just significantly more affected than the other two families.

Influence of age of the planting—It is a matter of general experience that plantings begin to give trouble at about three years of age and are free by the age of about seven years. Isolated cases may occur on trees as young as one year. In November 1956 the lower side of leaning stems of five adjacent field buddings of Tjir 1 on an estate in the Mukim of Ulu Bernam were infected; the nearest known pink disease cases were half a mile distant. At the other extreme trees that have been in tapping several years may be infected, but such cases remain in the canopy where they do no harm.

The Laikhê census (Borget 1947, 1948a) showed 4 to 5 years to be the most susceptible age, and similar results emerge from the census at Sungei Buloh.

Mechanism of resistance—Just as the thickness of cuticle is the first factor one suspects to account for resistance to a leaf disease, so bark thickness may be significant in diseases of stems. Measurements made in Indochina at three heights—2, 3, and 4 metres—on five different clones of varying degrees of susceptibility, showed no correlation between bark thickness and susceptibility (Borget 1949). Measurements of water content of the bark at heights of 2 m and 3.5 m also failed to show consistent differences (Borget 1949, Tixier 1950). It has been suggested that differences in bark thickness in different parts of the same tree are related to shade or sun (Butler 1918b). However, resistance may depend not on a physical barrier, but on the special reaction to invasion of the living cells of the bark. Even if this does not occur it might be that the less susceptible clones are not showing true resistance, but disease avoidance, dependent upon the texture of the bark being unfavourable to spore lodgement; or the habit of the tree being inimical to infection because of an open canopy allowing drying out more readily than if compact. The latter explanation has been used (Butler 1918a) to account for the high susceptibility of *Cinchona ledgeriana*, with its dense growth, and the comparative resistance of *Cinchona succiruba* with open growth. Both species are equally susceptible to inoculation. Artificial inoculation cannot be expected to yield much information bearing on resistance. Even when spores are used, or other means comparable with natural conditions, the act of inoculating may overcome some natural resistance. Using pieces of infected wood, it is doubtful whether any natural resistance to infection would have a chance to show. A trial was carried out at the R.R.I. Experiment Station in which fifty trees of clone RRIM 501 and fifty of Tjir 1 were inoculated, using prepared Alkathene wrappings, in all instances on branches 2 cm in diameter exposed to sunlight. Examination after six weeks showed 37 to have infected Tjir 1 compared with 34 for RRIM 501; yet the latter clone is known to be much more susceptible to natural infection than the former.

The factor conferring resistance, whatever the mechanism may be, is heritable, to judge from the genetic history of the clone RRIM 618, of which the parents were Lunderston N and RRIM 501. Both RRIM 618 and RRIM 501 are very susceptible to pink disease. Lunderston N is also one of the parents of RRIM 501, the other being AVROS 44. Of the two other RRIM '500' series clones from the same parentage, RRIM 509 has shown no special susceptibility and RRIM 505 has not been available for assessment. It is expected that young buddings of Lunderston N now under observation will show susceptibility when they reach the age.

ENVIRONMENT

Information relating to the favourable environment for the disease comes from reports received from all over the country: through advisory work, records from the Institute's clone trials, and in response to specific enquiries sent to estates. Differences in climate, soil, and, to a slight extent, in biological factors, can be recognised throughout the country. Further information on the significance of soil and biological factors comes from a census of diseased trees in experiments laid down for some other purpose, especially when the areal distribution of diseased trees is recorded. The experimental approach is restricted to modifying the local environment by shading, bagging, watering, manuring etc.

Climatic Factors in the Environment

With the even temperatures—70°F at night to 90°F during the day — prevailing over the Malayan rubber lands, rainfall is the only climatic factor that varies markedly

in different parts of the country and from one time of the year to another (MALAYAN METEOROLOGICAL SERVICE 1957). Moreover, this geographical variation of rainfall is connected with variation in disease intensity as can be shown in a distribution map (*Figure 1*). Pink disease is worst in the Taiping district which is exceptionally wet; the next worse zone being near Tanjong Malim.

The importance of rainfall is also clearly seen in Indochina, where the Cambodian plantations have a less rainy climate and a clearer dry season as compared with the hevea areas of Cochin China (BORGET 1948b). Evidence that the rainy season encourages pink disease by its effect on tree growth, rather than by increased humidity, comes from an experiment at Laikhê, in which branches were enclosed in a glass case to maintain humidity during the prolonged dry season from February to June (BORGET 1948b). Artificial inoculations made under these conditions of high humidity failed to infect. A similar effect has not been observed using Alkathene chambers in Malaya, but there is no prolonged dry season to produce a marked result. It was noticed that the high humidity of the Alkathene chamber did not encourage formation of a hymenium on the surface of the pink crust, although the hymenium is formed in nature under conditions of high humidity.

It is difficult to assess the importance of air movement in influencing the disease, either within the immediate vicinity of a planting, by its effect on patches of mist, or generally. A general influence of sea breezes has been suggested as an explanation for the rarity of pink disease in the coastal areas.

Soil Factors in the Environment

Soil type—The rarity of even light attacks of pink disease in coastal plantings can be related to the occurrence of alluvial soils. A maritime climate may have some influence as suggested above, and in support of this it is observed that the soils in Malacca are generally free from pink disease although not alluvial.

A survey carried out by post in 1956 was made by taking a random sample of rubber estates over 500 acres (i.e. planting units that might reasonably be expected to have areas of susceptible age, and to reply to the enquiry) and known to have purchased budwood of the susceptible clone RRIM 501. A personally-signed letter was sent to each estate, enclosing a reply-paid addressed postcard. The manager was asked to indicate whether the incidence could be described as heavy, medium, light, or negligible, and to state if the soil was alluvial clay or peat. Of the 300 cards sent out 163 replies reported plantings of RRIM 501 of susceptible age, and the distribution, after checking by visits in some cases, was as follows:

	Negligible	*Light*	*Medium*	*Heavy*
Inland soil type	22	21	24	35
Coastal soil type	51	7	3	—

This information was combined with data from advisory correspondence and personal observations to give a total of 242.

Methods of cultivation—At Laikhê a block of four-year-old trees of six clones had been given four different cultivation treatments: *Pueraria* turned-in, ploughing, clean-weeding, and *Pueraria* cover. The census (BORGET 1947, 1948a) showed no significant differences between them. All the areas included in the census at Sungei Buloh had carried either legume covers or *Mikania scandens* sprayed back at intervals, but with no areas large enough for valid statistical comparisons to be made of disease incidence.

Manuring—At Laikhê a manuring experiment with five-year-old clone Dj 1 on AVROS 163 illegitimate stock was availabe for statistical analysis of the numbers of

diseased trees. Eight manurial treatments had been given consisting of different combinations of nitrogen, potassium, and phosphorus; no significant effect of manure was demonstrated in a census of diseased trees (Borget 1947, 1948a). Girth measurements made in an area that had been laid out as an NPK manurial experiment showed that the deleterious effect of pink disease was the same whatever the manuring treatment (Tixier 1950).

Two areas that were available for similar observations at Sungei Buloh were manurial experiments of the R.R.I. Soils Division planted throughout with trees of a susceptible clone and age (RRIM 501 four years old). In one experiment, different frequencies of application of nitrogen, phosphorus, and potassium were being compared; statistical analysis of the counts of diseased trees showed no significant treatment differences. In the other experiment, the effects of nitrogen, phosphorus and potassium were being compared at three different levels, singly and in all combinations; different levels of phosphate or potash had no significant effect, but the effect of nitrogen was highly significant in respect of the increased number of trees affected with pink disease. (Table 4).

In the other experiment, to test the affect of heavy potash manuring, five rows of approximately 150 trees spaced 4 ft apart in the rows were given a broadcast dressing of muriate of potash every three months from an age of 3½ years from budding to 5 years. The treated rows were in a 60 ft avenue planting and were chosen so that they compared with similar untreated rows from which they were separated by an avenue 120 ft wide, in the middle of which a guard row grew. No significant difference between the incidence in treated and untreated rows was noticed while the experiment was in progress. After the final potash application all cases of pink disease were sprayed with Bordeaux mixture, any that survived being subsequently pruned. After six months to allow for reinfection of the area, the number of diseased trees was counted. Of the treated trees 17.6% were infected, and of the control 27.7%. However the difference was not significant.

Biological Factors in the Environment

It has long been accepted (South 1915) that large areas of forest favour development of the disease in adjacent rubber estates. The original distribution map (see page 276) showed the complex interrelationship of lowland forest and hevea throughout the country. A map (Sharples 1936), which purports to illustrate the type of situation where serious pink disease centres are found, covers a portion of the Batang Padang/Lower Perak District boundary where the proportions of rubber and forest lands are typical of most of the country. The disease is severe on the estates round Tanjong Malim on the Selangor/Perak border, and here there are large tracts of forest. However it is absent from other places where the presence of forest might be expected to encourage it.

It is usually suggested that the disease is harboured by certain forest plants. This is likely in view of the great host range of *Corticium salmonicolor* and the large number of species in the forest. However, frequent inspection of forest areas has not revealed any diseased trees. Other ways in which the proximity of forest might exert an effect on the incidence of pink disease in hevea, are by modifying the local climate and by harbouring animals which spread the disease. There is no evidence bearing on these matters. Insects have been found grazing the hymenial layer (*Figure 14*) and their presence might be influenced by trees of species other than hevea.

Planting density—The proximity of the neighbours with which a tree is growing has an important biological effect; they not only compete, but modify the local climate and may act as sources of infection. The effect is, naturally, more marked with closer

Table 4. Incidence of Pink Disease, as Percentage of Trees Affected, in the Combined Three Blocks (Totalling Approximately 120 Trees) of an Experiment Comparing Three Different Levels of Nitrogen, Phosphorus, and Potassium

N	P	K	2nd census	3rd census	4th census	N	P	K	2nd census	3rd census	4th census	N	P	K	2nd census	3rd census	4th census
0	0	0	23.7	18.4	31.6	1	0	0	21.4	26.8	54.5	2	0	0	26.8	40.2	47.3
0	0	1	17.7	23.9	43.4	1	0	1	14.8	22.6	39.1	2	0	1	28.3	22.8	49.6
0	0	2	16.7	17.5	51.8	1	0	2	24.3	21.7	33.9	2	0	2	26.5	35.7	48.2
0	1	0	17.2	22.4	37.9	1	1	0	20.5	19.7	47.9	2	1	0	31.6	29.2	49.6
0	1	1	10.3	23.3	43.1	1	1	1	28.4	19.3	39.5	2	1	1	33.0	42.6	61.7
0	1	2	20.2	16.7	50.0	1	1	2	20.4	20.4	24.8	2	1	2	35.3	37.0	55.5
0	2	0	27.1	23.7	47.4	1	2	0	19.1	25.2	42.6	2	2	0	26.7	36.2	53.4
2	0	1	18.6	16.8	31.9	1	2	1	20.9	24.3	38.3	2	2	1	26.3	36.0	49.1
0	2	2	11.6	5.4	38.4	1	2	2	28.9	34.2	54.4	2	2	2	19.7	30.8	43.6

planting distances and as the trees grow older. Counts were made at Laikhê (Borget 1947, 1948a, b) in two 63-acre planting distance experiments with trees between five and six years old. In the first experiment, consisting of Tjir 1 and AVROS 163 illegitimate seedlings, the spacings 8ft x 8ft, 11ft x 11ft, and 10ft x 20ft had significantly less disease than the 13ft x 13ft, 15ft x 15ft, and wider spaced plots. The second experiment failed to show any significant difference between plots, but it consisted of the somewhat resistant clone AVROS 50 and included only 13ft x 13ft among the closer spacings. In another experiment, consisting of trees spaced out on a triangular pattern of progressively decreasing densities, the same indication of less disease at the greater densities was found (Campaignolle & Bouthillon 1955). It was suggested that the microclimate which enables the *C.salmonicolor* spores to infect was found at the main forks in the more open plantings, but in the upper branches in the denser plantings.

An experiment comparing planting distances was available for study on the Sungei Buloh Experiment Station, where 49 acres had been planted with four clones (Table 5). Any significant difference between distances is marked by differences between clones.

Table 5. Numbers of Infected Trees of Four Clones at Different Spacings

Spacing	RRIM 513		RRIM 527		LCB 1320		Tjir 1	
	total	pink	total	pink	total	pink	total	pink
30ft x 8ft	168	3	170	18	168	27	170	50
50ft hedge	283	8	285	19	282	29	284	22
65ft hedge	275	4	273	3	276	25	278	27
20ft x 12ft	92	8	92	—	94	22	94	1
80ft hedge	263	3	268	2	265	15	267	10

Marginal effects—A census taken at Laikhê (Borget 1949) showed there to be a larger number of cases of infection in the marginal rows of trees than in the centre of the plantation, which indicated that light is important for the development of the fungus.

Transmission from neighbour to neighbour—If the infection spreads from tree to tree cases will not be distributed at random throughout a plantation, but will be associated with each other. A simple statistical test (van der Plank 1946) can determine whether the distribution is random or not, provided, of course, that the position of the infected trees in the field is known. This was possible at Laikhê (Borget 1949) and the test was applied to counts from 13 blocks representing 67,000 trees. The conclusion was that there was no transmission from any tree to its neighbour. This was confirmed by observations in a plantation where the trees had been planted in pairs. Similar counts were made in three fields at Sungei Buloh, and in one field on a severely affected commercial planting. The fields chosen for counting had all been planted with RRIM 501, which eliminated variation due to clone. They contained 2345, 4617, 1120, and 3228 trees respectively. If the statistical test is applied to the fields as a whole, ignoring variation in planting distance, margin lengths, and manurial treatment, the distribution of diseased plants appears to be random. However, evidence for neighbour-to-neighbour transmission appears when variation between plots is taken into account, as illustrated in plot counts from a fourth field (Table 6), where a general count had shown random distribution.

TABLE 6. EVIDENCE FOR NEIGHBOUR-TO-NEIGHBOUR INFECTION IN DUPLICATE PLOTS OF FOUR CLONES AT DIFFERENT SPACINGS

Spacing	RRIM 513		RRIM 527		LCB 1320		Tjir 1	
30ft x 8ft	*		No		*	No	No	No
50ft hedge		*	No		*	*	No	
65ft hedge	*	*		No	No	No	No	
20ft x 12ft			No		No	No	No	
80ft hedge			*		No	No	No	

* : neighbour-to-neighbour infection suggested by non-random distribution
No : random distribution

Alternative hosts—Rant (RANT 1912) records *C.salmonicolor* on 141 species in Java. He was able to inoculate cinchona from coffee, tea, cacao, hevea, as well as from other varieties of cinchona. There did not appear to be strains confined to one or more host.

Pink disease has been recorded in Malaya on the following plants, all of them cultivated trees or shrubs: coffee, cacao, a species of *Gardenia*, *Cassia*, and *Hibiscus*, on camphor, horse mango, jack-fruit, durian, lime, langsat, belimbing and mango. (BROOKS & SHARPLES 1914): also three species of bush cover: *Tephrosia hookeriana*, *Indigofera arrecta*, *Clitoria cajanifolia* (SHARPLES 1915). The bush cover plants: *Tephrosia*, *Crotalaria usaramoensis*, and *Desmodium ovalifolium* were in 1936 so severely attacked on an estate in Ulu Bernam Mukim, in the district of Ulu Selangor that regular rounds of fungicidal treatment were being given. In contrast with the earlier prominence of the disease on plants other than hevea, post war observation by both the Rubber Research Institute and the Department of Agriculture has produced no records of new host species and only two confirmations on old ones—cacao and lime.

CONTROL

Bordeaux mixture was being used to control pink disease fifty years ago in Malaya (GALLAGHER 1909), and Southern India (ANSTEAD 1911). Workers in Java (RANT 1912) were unaware of this fact at least until the year 1912 (PETCH 1912) although Bordeaux mixture was being used in Java by 1914 (RUTGERS & ARENS 1914). In Malaya, following the practice already in operation in Southern India, Bordeaux mixture was recommended, (BANCROFT 1913). In Indochina when the plantations were first established coal tar or Bordeaux mixture was used (VINCENS 1920). Later, emphasis was placed on oil/tar mixtures (BUGNICOURT 1937).

Post-war Field Experiments in Indochina

The only difference in treatment of pink disease available for census at Laikhê was in whether or not scraping had been carried out prior to applying coal tar (BORGET 1947, 1948a). Comparison showed significantly more repeat attacks where scraping had been done.

The method of treatment became a matter of considerable concern in Indochina when the plantations were rehabilitated after the war (BORGET 1948b). A few estates continued the pruning/coal tar method, with or without scraping. Others abandoned attempts to control the disease. A concentrated Bordeaux mixture with addition of a sticker was introduced, made up from 7 to 10 parts of copper sulphate, 7 to 10 parts of quicklime, and 2 to 4 parts fish glue or rice paste in 100 parts of water. (BORGET 1949, TIXIER 1950, 51, 52).

Post-war Field Experiments in Malaya

Advice differing little from that of Brooks and Sharples was the standard recommendation up to the war, and even continued after the war. Routine treatment was suspended in some areas and an increase noted (Altson 1953a). Fylomac 90 was tested as a substitute for Bordeaux mixture and found suitable (Altson 1953b). Advice based on these observations was incorporated into a new advisory leaflet on pink disease. (Pathological Division 1951). Further opportunities for experimental work came with the earliest post-war plantings reaching susceptible age; asphalt-kerosene mixture was found to be unsatisfactory (Newsam 1958a), and spraying of every attacked tree to be a better method of control than prophylactic spraying of all trees or spraying in the early stages of infection and pruning advanced cases (Newsam 1958b). As a result of these experiments the advice was modified to that given in *Planters' Bulletin* (R.R.I.M. 1955). Experience at Sungei Buloh has led to discontinuation of pruning, and reliance on fungicides for control of the disease. This is the current advice being given to estates. (R.R.I.M. 1958).

Experimental work is now confined to routine testing of commercially available applicators and fungicides. Tests are conducted by treating small numbers of diseased trees and estimating the recovery of each individually. Methods using counts of the number of diseased trees per replicated plot require much larger numbers of trees than are available.

SUMMARY

Pink disease is a disease of hevea 3 to 9 years old first recorded in Malaya by Ridley in 1904 and becoming of concern there about 1909. It is widespread in the Asian, African, and American hevea areas. Its economic importance has been exaggerated in the past, as it rarely kills a complete tree and is amenable to treatment. Basidiospores 5.8 x 4.7 μ and conidia 12 μ in diameter are produced by the corticium and necator stages respectively; both spore types germinate rapidly. No method of inducing the fungus to spore in culture has been discovered. Successful inoculation has been achieved with mycelium in wood or bark, but not with spores. Spores, produced during times of maximum humidity, have been caught in the volumetric spore trap. Dissemination of basidiospores can be assumed to be by wind, and of conidia by droplets, but this has not been demonstrated. There is evidence for neighbour-to-neighbour spread.

The disease develops most rapidly on vigorous young branches, growing back to the fork. Mycelium penetrates to the pith. The disease may die out, and reappear during the next wet season. Clones RRIM 618, RRIM 501 are susceptible, followed by Tjir 1, other clones, and by PB 86 and Gl 1 which are less affected. The mechanism of resistance/susceptibility has not been discovered.

The most favourable environment is provided by a combination of wet season, inland soil, and districts of high rainfall. The disease is negligible on coastal soils even during the wet season.

Control is by fungicides applied from the ground by means of a long lance.

I record my appreciation of assistance from Dr A. Newsam with the presentation and from Mr A. C. C. Fong with the statistical analyses.

Pathological Division
Rubber Research Institute of Malaya
Kuala Lumpur

October

REFERENCES

ALTSON, R. A. (1953a) Pathological Division. Report for the year 1950. *Rep. Rubb. Res. Inst. Malaya* 1950.

ALTSON, R. A. (1953b) Pathological Division. Report for the year 1951. *Rep. Rubb. Res. Inst. Malaya* 1951.

ANSTEAD, R. D. (1914) Pink disease of para rubber and Bordeaux mixture. *Plant. Chron. 6*, 98.

BANCROFT, C. K. (1913) Miscellaneous botanical notes. *Agric. Bull. F.M.S. 1*, 218.

BERKELEY, M. J. & BROOME, C. E. (1873) Enumeration of the fungi of Ceylon II. *J. linn. Soc. 14*, 71.

BERNARD, C. J. (1906) Eene ziekte van Hevea, veroorzaakt door de djamoer oepas (Corticium javanicum Zimm.) *Teysmannia 17*, 318.. (reprinted in *Cultuurgids* 8,292).

BORGET, M. (1947) Répartition et intensité des attaques de Corticium à la Station de Laikhê. *Comité Technique Consultatif de l'I.R.C.I.* Communication 13.

*BORGET, M. (1948a) Répartition et intensité des attaques de Corticium à la Station de Laikhê. (Summary of BORGET 1947). *Cah. I.R.C.I. 3*, 62.

*BORGET, M. (1948b) Rapport de la Division de Phytopathologie. *Rapp. I.R.C.I.* 1947, 70-79.

*BORGET, M. (1949) Rapport de la Division de Phytopathologie. *Rapp. I.R.C.I.* 1948, 70-77.

BROOKS F. T. (1914) Pink disease. *Agric. Bull. F.M.S. 2*, 238.

BROOKS, F. T. & SHARPLES, A. (1914) Pink disease. *Bull. Dep. Agric. F.M.S.* 21.

BROOKS, F. T. & SHARPLES, A. (1915) Pink disease of plantation rubber. *Ann. appl. Biol., 2*, 58.

*BUGNICOURT, F. (1937) Sur quelques maladies de l'hévéa et du théier A. hévéa *Bull. écon. Indoch. 40*, 723.

BUTLER, E. J. (1918a) *Fungi and Disease in Plants*. Thacker Spink & Co. Calcutta.

BUTLER, E. J. (1918b) Immunity and disease in plants. *Agric. J. India 5*, 10.

CAMPAIGNOLLE, J. & BOUTHILLON, J. (1955) Contrôles phytosanitaires *Rapp. I.R.C.I.* 1954, 199-201.

DASTUR, J. F. (1946) Notes on *Corticium album* and *C.salmonicolor*. *Curr. Sci. 15*, 193.

GALLAGHER, W. J. (1909) A preliminary note on a branch and stem disease of *Hevea brasiliensis*. *Bull. Dep. Agric. F.M.S. 6*.

LANGFORD, M. H. (1953) Hevea diseases of the Amazon Valley *Bol. tec. Inst. Agr. do Norte* 27.

LEE, H. A. & YATES, H. S. (1920) The distribution of pink disease. *Philipp. agric. Rev. 13*, 115.

MALAYAN METEOROLOGICAL SERVICE (1957) *Climatological Summaries Part II—Rainfall.*

MARTIN, W. J. (1947) Diseases of the hevea rubber tree in Mexico, 1943-46. *Plant. Dis. Reptr. 31*, 155.

MAŚSEE, G. (1898) Fungi exotici. *Kew Bull. 138*, 119.

MENDES, L. O. T. (1947) Sôbre a ocorrência da Rubelose na Seringueira. *Rev. Agric., Piracicaba 22*, 157-160. (*Biol. Abst. 24*, 3540).

NEWSAM, A. (1958a) Pathological Division. Report for the year 1953. *Rep. Rubb. Res. Inst. Malaya* 1953.

NEWSAM, A. (1958b) Pathological Division. Report for the year 1954. *Rep. Rubb. Res. Inst. Malaya* 1954.

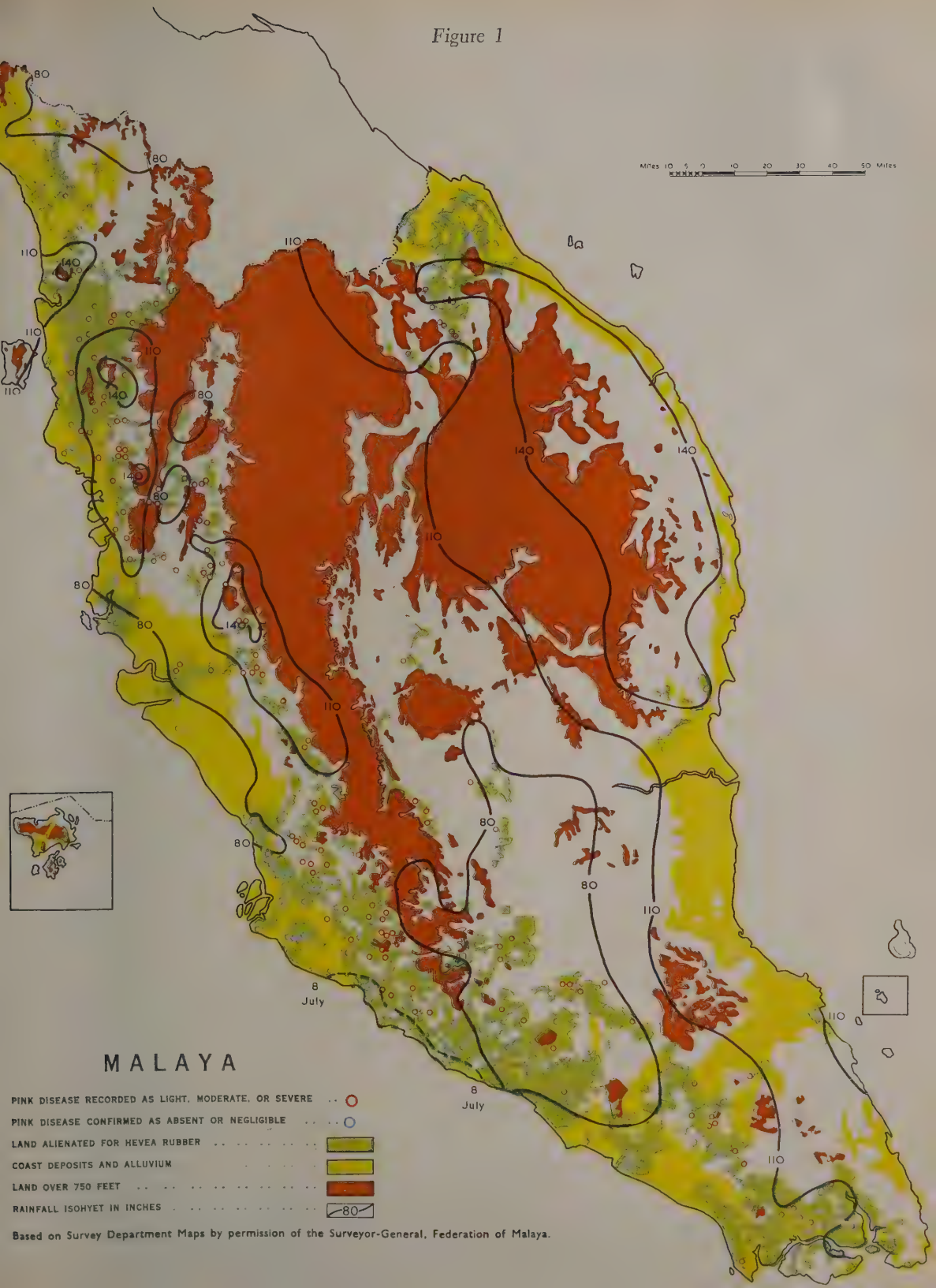
NOWELL, W. (1916) Pink disease in the West Indies. *Agric. News Barbados 5*, 238.

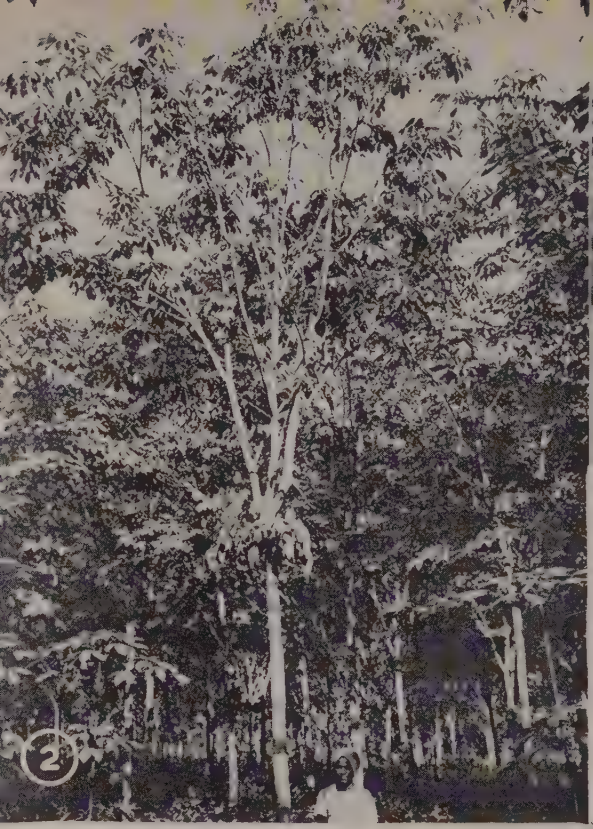
PATHOLOGICAL DIVISION (1951) Pink disease. *Circ. Rubb. Res. Inst. Malaya* 33.

Petch, T. (1908) Die Pilze von Hevea brasiliensis Z. *Pflkrankh. 18*, 88.
Petch, T. (1909) A bark disease of hevea, tea, etc. (*Corticium javanicum* Zimm). *Circ. agric. J. Ceylon 5*, 189.
Petch, T. (1911) *Pink Disease. The Physiology and Diseases of Hevea brasiliensis*, 208. Dulau & Co. London 1911.
Petch, T. (1912) Pink disease in Java. (Review of Rant 1912) *Trop. Agriculturist* 39, 44 reprinted in *Plant. Chron. 5*, 451.
Rant, A. (1912) Ueber die djamoer-oepas-krankheit und ueber das *Corticium javanicum* Zimm. *Bull. Jard. bot. Buitenz. Ser. 2. No. 4.*
Rhind, D. (1926) The diseases of Para rubber in Burma. *Bull. Dep. Agric. Burma* 14.
Ridley, H. N. (1897) Coffee diseases. *Agric. Bull. Malay Pen. 7*, 147.
Ridley, H. N. (1904) Parasitic fungi on *Hevea brasiliensis*. *Agric. Bull. Str. Malay St. 3*, 173.
Ridley, H. N. (1905) A bark fungus on Para rubber. *Agric. Bull. Str. Malay St. 4*, 423.
Ridley, H. N. (1906) The bark fungus of Para Rubber. *Agric. Bull. Str. Malay St. 5*, 69.
R.R.I.M. (1955) Pink disease. *R.R.I. Plant. Bull. 18*, 50.
R.R.I.M. (1958) Pink disease control. *R.R.I. Plant. Bull. 37*, 87.
Rutgers, A. A. L. & Arens, P. (1914) Diseases of *Hevea brasiliensis* in Java. *Rubber Recueil. International Rubber Congress & Exhibition Batavia* 1914, 130.
*Saccas, A. M. (1953) Les principales maladies cryptogamiques de l'hévéa en A.E.F. *Agron. trop., Nogent 8*, 176.
Sharples, A. (1915) Host plants of pink disease in Malaya. *Agric. Bull. F.M.S. 3*, 203.
Sharples, A. (1936) *Diseases and Pests of the Rubber Tree*. Macmillan & Co, London 1936.
South, F. W. (1915) Notes on the distribution and field treatment of pink disease. *Agric. Bull. F.M.S. 4*, 47.
South, F. W. (1917) Application of the agricultural pests enactment. *Agric. Bull. F.M.S. 5*, 349.
South, F. W. (1921) Distribution of pink disease in Federated Malay States mukims. *Agric. Bull. F.M.S. 5*, 279.
South, F. W. (1926) Annual Report of the Chief Field Officer, 1925. *Malay. agric. J. 14*, 146.
Thompson, A. (1924) Annual Report of the Mycologist 1923. *Malay. agric. J. 12*, 246.
*Tixier, P. (1950) Rapport de la Division de Phytopathologie. *Rapp. I.R.C.I.* 1949, 74-78.
*Tixier, P. (1951) Rapport de la Division de Phytopathologie. *Rapp. I.R.C.I.* 1950, 62-65.
*Tixier, P. (1952) Rapport de la Division de Phytopathologie. *Rapp. I.R.C.I.* 1951, 76-81.
van der Plank, J. E. (1946) A method for estimating the number of random groups of adjacent diseased plants in a homogeneous field. *Trans. roy. Soc. S. Afr. 31*, 269 (from *Rev. appl. Myc. 26*, 257).
Vincens, F. (1920) Maladie rose et chancre des branches. *Bull. agric. Saigon* 2, 321.
Zimmermann, A. W. P. (1899) Sammebreferate uber die tierischen und pflanzlichen Parasiten der tropischen kulturpflanzen. *Zbl. Bakt. Abt. 2 Bd. 5*, 582.
Zimmermann, A. W. P. (1901) Ueber einige an tropischen Kulturpflanzen beobachtete Pilze. *Zbl. Bakt. Abt. 2 Bd. 7*, 102.

*English translation available from the library of the Rubber Research Institute of Malaya.

Figure 1


Miles 10 5 0 10 20 30 40 50 Miles
80
110
140
8 July
8 July
MALAYA
PINK DISEASE RECORDED AS LIGHT, MODERATE, OR SEVERE
PINK DISEASE CONFIRMED AS ABSENT OR NEGLIGIBLE
LAND ALIENATED FOR HEVEA RUBBER
COAST DEPOSITS AND ALLUVIUM
LAND OVER 750 FEET
RAINFALL ISOHYET IN INCHES
80
Based on Survey Department Maps by permission of the Surveyor-General, Federation of Malaya.



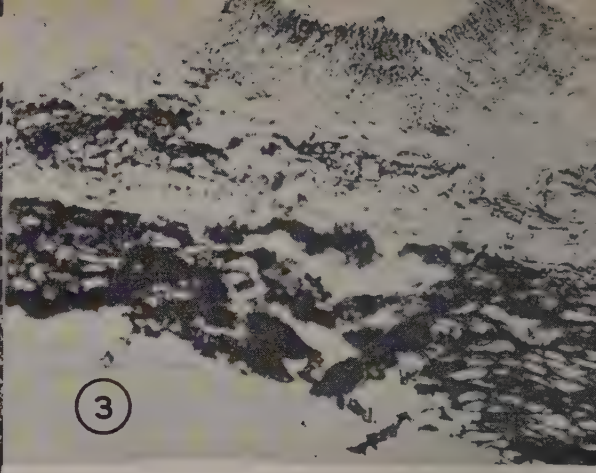
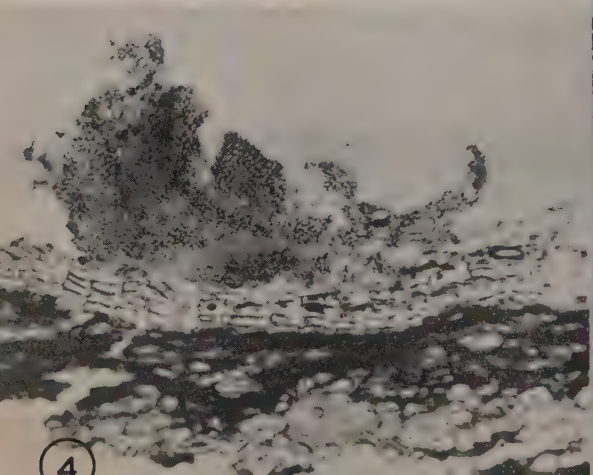


Figure 2. A four year old tree of which the whole crown is dying from pink disease. The appearance of subsidiary shoots is seen below the main fork.

Figure 3. Section through a fragment of bark bearing the pink crust with corticium stage.

Figure 4. Section through a fragment of bark bearing a necator pustule.

Figure 5. The spore trap in position by a five-year-old tree.



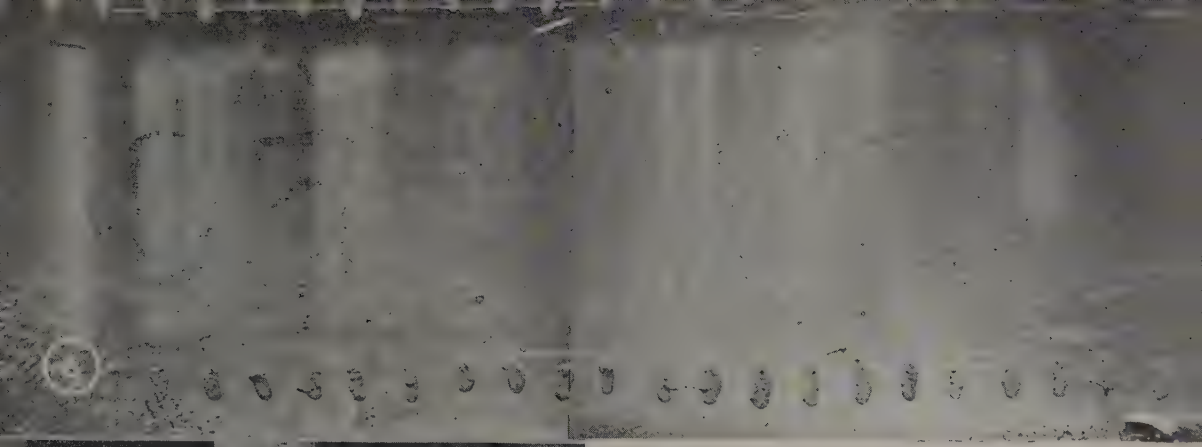


Figure 6. Spore trace taken within 30 cm of sporulating surface.

Figure 7. Inoculum being placed in position on a susceptible branch.

Figure 8. The infected branch pointed out by the arrow in Figure 9.

Figure 9. The 30 ft inoculation mast in position beside a four-year-old tree. Arrow pointing to an infected branch.

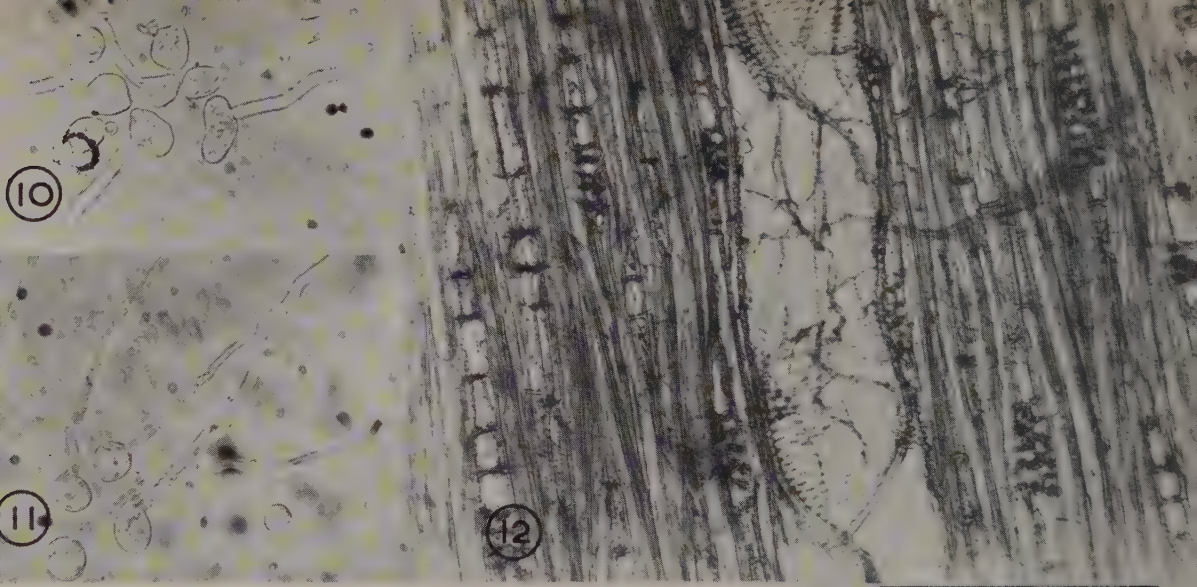


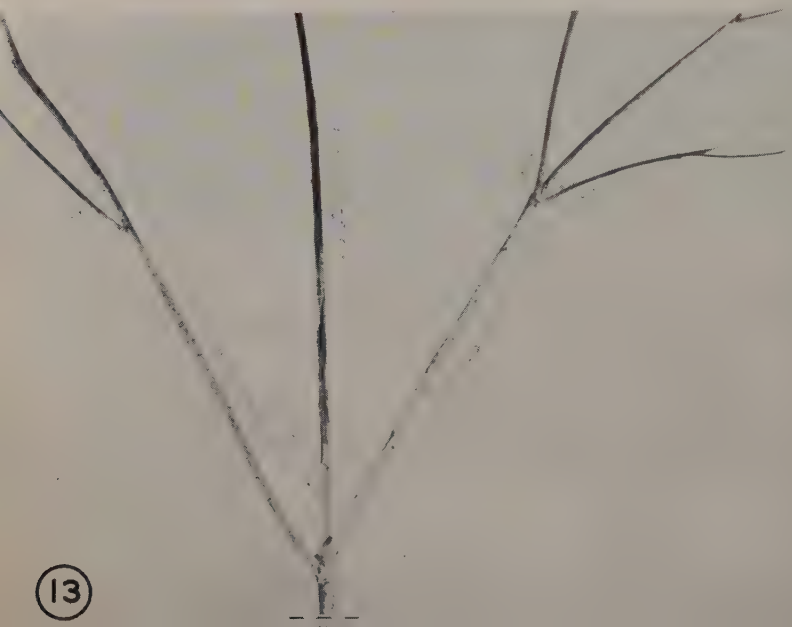
Figure 10. Germinating necator spores after one hour.

Figure 11. Germinating basidiospores after two hours.

Figure 12. L.S. infected wood showing mycelium of C.salmonicolor in vessels.

Figure 13. Branch of three-year-old tree on which advance of infection has been recorded by pins inserted at approximately weekly intervals.

Figure 14. Crust surface grazed by beetles.



JOURNAL

of the

RUBBER RESEARCH INSTITUTE

of

MALAYA

VOLUME 15, PARTS 1-5, 1957-8

Communications 301-23

27 MAY 1960

Correct abbreviation for citing references, according to the World List of Scientific Periodicals:

J. Rubb. Res. Inst. Malaya

Printed by
The Malaya Publishing House Ltd.
for
The Rubber Research Institute of Malaya,
Kuala Lumpur, Selangor

CONTENTS OF VOLUME 15

PART 1

	Communication	Page
Cover Plants in Rubber Cultivation. *G.A. Watson* ..	301	2
Bacterial Culture Media from Hevea Latex. *D.H. Taysum* ..	302	19
A Magnesium-Manganese Interrelationship in the Mineral Nutrition of *Hevea brasiliensis*. *E.W. Bolle-Jones* ..	303	22
Manuring Hevea: Effects of Fertilisers on Growth and Yield of Mature Rubber Trees. *G. Owen, D.R. Westgarth and G.C. Iyer*	304	29

PART 2

Stimulation of Bark Renewal of Hevea and its Effect on Yield of Latex. *P. de Jonge* ..	305	53
Microflora of Hevea Latex. 1. Growth Media. *D.H. Taysum* ..	306	72
Susceptibility of Hevea Seedlings to *Helminthosporium heveae* Attack in Relation to their Nutrient Status. *E.W. Bolle-Jones* and *R.N. Hilton* ..	307	80
Flame Photometric Determination of Potassium and Calcium and the Chemical Estimation of Phosphorus, Magnesium and Manganese in Leaves of Hevea. *E.W. Bolle-Jones, V.R. Mallikarjuneswara and K. Ratnasingam* ..	308	86
Effects of Mineral Status and Light on Rubber Formation in Hevea. *E.W. Bolle-Jones and V.R. Mallikarjuneswara* ..	309	95

PART 3

Foliar Diagnosis of Mineral Status of Hevea in Relation to Bark Analysis. *E.W. Bolle-Jones* ..	310	109
Cobalt: Effects on the Growth and Composition of Hevea. *E.W. Bolle-Jones and V.R. Mallikarjuneswara* ..	311	128
Molybdenum: Effects on the Growth and Composition of Hevea. *E.W. Bolle-Jones* ..	312	141
Zinc: Effects on the Growth and Composition of Hevea. *E.W. Bolle-Jones* ..	313	159
Nitrogen Fixation by *Centrosema pubescens*. *G.A. Watson* ..	314	168

	Communication	Page
PART 4		
Effects of Cover Plants on Soil Nutrient Status and on Growth of Hevea. 1. Laboratory Studies on the Mineralisation of Nitrogen in Different Soil Mixtures. *M.M. Guha and G.A. Watson* ..	315	175
Poisoning Experiments with *Hevea brasiliensis*.		
I. Preliminary Trials — Destruction of Trees with 2,4-D and 2,4,5-T. *E.D.C. Baptiste* ..	316	189
II. Results of a Further Tree Poisoning Experiment with 2,4,5-T. *E.D.C. Baptiste and P. de Jonge* ..	317	193
Natural Rubber Latex as Initiator for Vinyl Polymerisation. *B.C. Sekhar* ..	318	205
Control of *Coptotermes curvignathus* Holmgren with Chlorinated Hydrocarbons. *A. Newsam and B. Sripathi Rao* ..	319	209
Superior Processing Rubber Masterbatch. *B.C. Sekhar and G.W. Drake* ..	320	216
Inoculation Experiment with *Fomes lignosus*, Klotzch. *K.P. John* ..	321	223
PART 5		
Defoliation of *Hevea brasiliensis* by Aerial Spraying. *F.W. Hutchison*	322	241
Pink Disease of Hevea Caused by *Corticium salmonicolor*. *R.N. Hilton* ..	323	275

TO SUBSCRIBE to this journal you need only remit $15 (Malayan) to The Rubber Research Institute of Malaya, P.O. Box 150, Kuala Lumpur, together with your order.

A statement of account will be sent to you after the end of each calendar year. Your subscription will lapse only if you fail to renew your deposit when this is exhausted; you do not need to remind us in the new year.

Your deposit will also cover additional requirements for R.R.I. publications, such as a subscription to *Planters' Bulletin*, our advisory organ for rubber estates, or any extra copies and back issues which you may request from time to time. A price list and order form are available.

BACK ISSUES of this journal from mid-1952 onwards are available, but many prior issues are out of stock. As a key to the contents of back issues we recommend the subject index to Volumes 1 to 20 (1928-50), price $1, together with the separate contents lists (gratis) for Volumes 13 and 14 (1951-6). Our price list states which issues are no longer available.

Printed by The Malaya Publishing House Ltd
for The Rubber Research Institute of Malaya
Kuala Lumpur, Selangor.

RUBBER RESEARCH INSTITUTE OF MALAYA
R
R
I